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ABSTRACT

This curriculum framework document was developed to define what students must learn in specific subject areas to ensure their ultimate success. This document provides guidance in the disciplines of mathematics, science, and technology. The purpose of these materials is to set content strands and performance indicators for all students in the school system. Three major sections include content standards and technology connections, foundation skills and curriculum integration, and using this document to plan for instruction. The content strands for mathematics feature number sense and estimation; number systems; patterns, relationships, and functions; geometry and spatial sense; measurement; probability and statistics; and algebraic concepts and operations. The content strands for science are scientific inquiry, life science, physical science, space sciences, and earth science. The content topics for technology include service learning and investigations, technology use reviews, integrated approach technologies, and everyday applications of technology. (ASK)

MATHEMATICS, SCIENCE and TECHNOLOGY

CURRICULUM FRAMEWORK

CENTER FOR SYSTEMIC EDUCATIONAL CHANGE

District of Columbia Public Schools

REVISED EDITION

MATHEMATICS -- SCIENCE -- TECHNOLOGY

CURRICULUM FRAMEWORK

Grades K-12

Revised Edition

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Chief State School Officer

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District of Columbia Public Schools

REVISED EDITION

CENTER FOR SYSTEMIC EDUCATIONAL CHANGE

DISTRICT OF COLUMBIA PUBLIC SCHOOLS

NOVEMBER 1995

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The revised edition of the Mathematics, Science and Technology Curriculum Framework represents a collaborative effort. The revision is based upon comments and recommendations from teachers, members of professional organizations, and staff at the Center for Systemic Educational Change in an effort to strengthen the first edition. The following team in the Center provided leadership for the creation of the revised document.

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DISTRICT OF COLUMBIA
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November 1, 1995

Dear Colleague:

The District of Columbia Public Schools is committed to our mission to provide a quality student-centered environment that fosters maximum learning by each student, enabling each to enjoy life-long learning while becoming a productive, global citizen. The depth of that commitment is expressed in BESST - Bringing Educational Services to Students, our bold initiative to prepare our students for the uncharted challenges of the 21st Century. Among other things, BESST provides schools with the option to design programs that are effective for the students they serve.

Goals 2000 and the Washington, D.C. Goals 2000 state that "Students will leave grades 4, 8 and 12 having demonstrated competency in challenging subject matter including English, mathematics, science, history and geography, and every school will ensure that all students learn to use their minds well, so they are prepared for responsible citizenship, further learning and productive employment in our modern economy."

To achieve these goals locally, educators and community members have drawn upon major efforts underway nationally to identify standards and benchmarks. This Curriculum Framework for Mathematics—Science—Technology is a true collaborative effort that translates into action "Making it happen for students, the BESST way." The Framework is designed to assist local schools in curriculum planning and development. It contains the essential elements that must be addressed in order to raise the levels of instruction and student performance based on the emerging national standards.

It is my belief that the Curriculum Framework for Mathematics—Science—Technology will help to further our efforts to make the D.C. Public Schools the number one school district in the nation.

Sincerely,

Franklin L. Smith
Superintendent of Schools
Chief State School Officer

INTRODUCTION

INTRODUCTION

The District of Columbia Public Schools has decided to implement a comprehensive approach to performance-based restructuring of its educational system. We believe this puts us in the vanguard of school districts across the country that are committed to major school improvement.

Over the past thirty years, American educators have been challenged to redefine and reorganize the way schools provide learning opportunities and experiences for students. Knowing that organizational patterns and expectations embedded in the schools of this century were designed to fit the needs and priorities of America's Industrial Age rather than the needs and realities of today's Information Age, educators have realized that more creative and effective educational structures are possible.

REFORM IN EDUCATION

Two major reform initiatives have emerged across the country that have changed the way we view teaching and learning:

1. Initiatives that embody the notion that all students can learn successfully if schools are systematically and comprehensively restructured to directly affect student learning success.

2. Initiatives that focus on clear definitions and demonstrations of student learning as the starting point and foundation of all curriculum design, instructional delivery and student and program assessment.

The first initiative addresses the systemic restructuring of schools and schooling; the second refers to a performance-based approach to teaching and learning.

When combined, these two initiatives represent the cutting edge of educational reform thinking today. They represent efforts to redefine and restructure how schools do their business. They are based on the knowledge, skills and learning abilities that students must have if they are going to be successful both in school and after graduation.

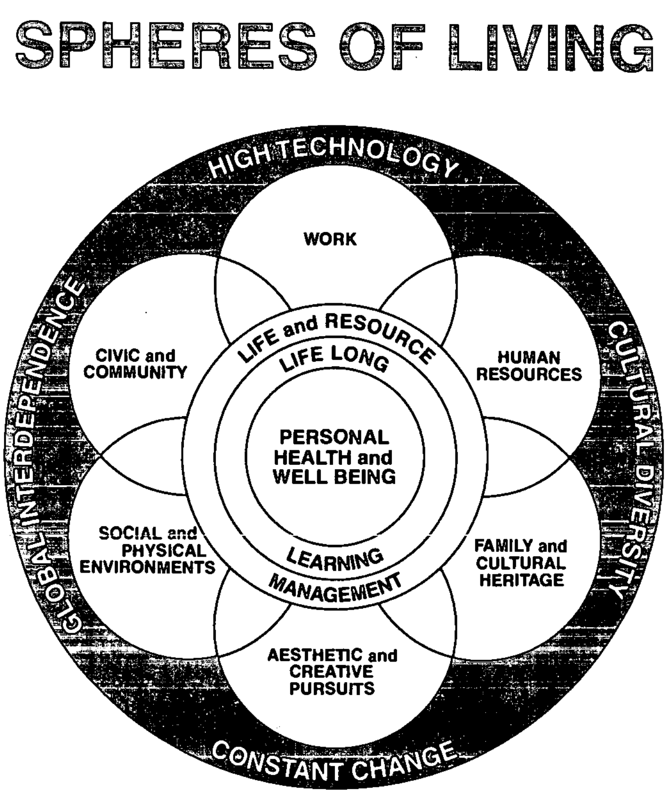

Figure 1

FOCUS ON THE FUTURE

While change of this magnitude represents a real challenge, the District has taken several steps toward designing and implementing this performance-based effort. As a first step, a planning group of staff and community representatives examined the context and environment in which students need to function effectively in order to be successful in the future. They then identified nine **SPHERES OF LIVING**, or arenas of application, where students will demonstrate their learned competencies.

- The **WORK** sphere reflects the individual's role and involvement in a changing work environment.
- The **HUMAN RELATIONSHIPS** sphere recognizes inter-human connectedness to one another, both in similar and diverse cultures.
- The **FAMILY AND CULTURAL HERITAGE** sphere embodies the language, symbols and valued actions of individuals and the multiple forms of modern family units which identify the diverse cultural heritage that underlies them.
- The **SOCIAL AND PHYSICAL ENVIRONMENTS** sphere embraces the natural and man-made properties and conditions to which the individual must adopt in order to assure viable living.
- The **CIVIC AND COMMUNITY** sphere includes those activities and responsibilities in the areas of political, economic and social relations.
- The **AESTHETIC AND CREATIVE PURSUITS** sphere involves those experiences and activities that enhance the beauty, depth, reaches and fulfillment of life.
- The **LIFE AND RESOURCE MANAGEMENT** sphere involves evaluating alternatives, setting priorities, coordinating time and resources, and accomplishing the tasks essential to living.
- The **LIFE LONG LEARNING** sphere recognizes the on-going pursuit and attainment of the knowledge and skills needed for successful living in a continuously changing world.
- The **PERSONAL HEALTH AND WELL-BEING** sphere involves the development and nurturing of the body, mind and spirit and their relationship.

These are illustrated in Figure 1. The **contexts of living** are those elements of the realm in which the spheres operate (depicted in the outer, shaded circle). Considering the key challenges and conditions students will face in those spheres, the planning group defined a set of learner outcomes for students that are deemed essential to their personal success and to the greater welfare of the community.

Schooling must be shaped and driven by the knowledge and skills students will require to meet the challenges and conditions of the rapidly changing, high-technology world in which they will live as adults. We call these *Learner Outcomes.* They serve as the engine that drives performance-based, systemic restructuring. This means that the curriculum framework, teaching practices, organizational structures, assessment designs and professional development plans must be aligned to foster and reflect these high-level learner outcomes in all of our students.

The planning group agreed that all students should emerge from the D.C. Public Schools as:

- **QUALITY PRODUCERS** who effectively communicate, compute, and use technology, information and different forms of creative expression
- **SELF-DIRECTED LEARNERS** who exhibit a love for learning, know how to learn, and demonstrate a sense of wonderment, curiosity and enthusiasm for new experiences
- **KNOWLEDGEABLE PROBLEM SOLVERS** who think independently and consider and apply a broad range of options and strategies in defining and resolving problems
- **INFORMED DECISION MAKERS** who anticipate the consequences of their actions and exercise integrity and sound judgment in making consumer and life decisions
- **COLLABORATIVE LEADERS** who use effective leadership and group skills to define work and community goals, initiate their accomplishment, enhance personal and others' self-esteem, and foster and sustain cooperative relationships within culturally diverse settings
- **COMMUNITY BUILDERS** who are responsible citizens and contribute their time, energies and talents to improve the health and welfare of themselves and others in their local and global environments

GUIDING PRINCIPLES

At the foundation of this performance-based approach to curriculum design and delivery is a set of guiding principles that underscore the District's commitment to all students. Our guiding principles are that

- All students are capable of learning, and there are no limits to learning.
- The dignity of the student and respect for his or her personal circumstances and cultural and language diversity should always be affirmed.
- Each student learns in his or her own way and at an individual pace.
- Learning is both an individual and social process.
- Learning requires the active participation of the learner.
- Caring, sensitive and responsive adults heighten the student's desire for learning and create conditions for success.
- The school, community and family must act in collaboration to support the student's learning.

ENSURING EQUITY AND A QUALITY EDUCATION FOR ALL STUDENTS

The District of Columbia of Public Schools (DCPS) is committed to educating all students in a child-focused, supportive, heterogeneous, age-appropriate, and dynamic classroom and school environment. This commitment is based on the belief that everyone has the right to achieve his or her potential within society. In our schools and classrooms, instruction and extracurricular activities invite participation of all students, inclusive of students with disabilities, students from diverse linguistic and cultural backgrounds, migrant students, and students who reside in temporary residences. Embedded in this commitment is the expectation that all of these students will achieve the same content standards and acquire the same foundation skills as described in this framework document.

All students bring gifts, talents, strengths, and challenges to the school environment. In classrooms responsive to diversity, students are encouraged to respect their linguistic and experiential resources . A language and culture-rich instructional environment maximizes cognitive and social development. Students' primary languages,

their stories, and the experiences that reflect their home cultures, all contribute to their learning and to the learning of their classmates. All students will gain competencies in English, while they are encouraged to maintain and strengthen their home language/dialect. To expect otherwise would be to marginalize some students and deny them participation in mainstream society.

An inclusive school environment values the rights of students with disabilities to be educated along with their peers in their community schools. Students are assigned to and receive related services such as speech/language therapy, and supports such as adaptive equipment and materials in the regular classroom whenever possible. Students with physical, cognitive, emotional and other challenges will have barrier-free facilities, adapted assessments, instruction, and materials in accordance with the goals and objectives of their IEP's and the DCPS Content Standards.

The DCPS commitment to educating all students extends to the provision of a safe and comfortable environment in which each student will attain DCPS Learner Outcomes. Given that students learn at different rates and in different ways, the role of the teacher and other support staff is to use a variety of teaching structures and strategies such as cooperative learning, individual instruction, continuous progress, authentic assessments, problem-based learning, peer tutoring, service learning and multi-modality instruction. This diverse and dynamic learning environment supports and maximizes student learning.

BEYOND THE SCHOOL

A critical aspect of the successful implementation of our reform is the involvement of parents and the community in the educational process. Parents must know and understand what we expect students to know and be able to do, so that they can become partners in the learning enterprise. Since the curriculum framework encourages students at all levels to participate in authentic performances in community as well as school situations, they will need contact with and assistance from experienced adults in all kinds of community roles. Teachers will become both facilitators of school learning and brokers of learning from outside experts who can offer students unique and relevant kinds of resources and experiences. Community partnerships and mentorships will become widespread as more and more community members recognize the role they can play in supporting the District's plan.

Realizing that technology can enhance the educational experience of every student, the District of Columbia Public Schools curriculum framework highlights how technology can be used to support student learning in each of the disciplines, and it encourages the increased use of technology over time.

Performance-based systemic restructuring requires new ways of thinking about our roles as educators, new kinds of tools, skills and resources for carrying them out, and new ways of using the time, space, resources, and talent at our disposal. It represents an exceptional opportunity for professional initiative and renewal with one key goal in mind: the present and future learning success of every student.

Maurice R. Sykes

Maurice R. Sykes
Deputy Superintendent
Center for Systemic Educational Change

Performance-Based Education and the Curriculum Framework

The District of Columbia Public Schools has taken a major step towards effectively educating its students through its decision to implement comprehensive Curriculum Renewal using Performance-Based Education. Our approach to Performance-Based Education is guided by the following assumptions:

- All children can learn and be held to high academic standards.
- Demonstration of learning in a variety of contexts is important evidence of learning.
- Teachers must be able to articulate criteria for evaluating student work in a course or unit before instruction begins.
- Students must know how they will be evaluated at the beginning of a course or unit of study.
- Academic learning, though grounded in subject area disciplines, must make connections between different disciplines and to life outside school.

To carry out these assumptions the Curriculum Renewal effort will address four questions:

(1) What must all students know and be able to do?

(2) How will we know when students have learned? And what will be acceptable evidence of that learning?

(3) What are the best ways to enhance student learning?

(4) How do we make academics relevant to students' lives and their future work?

PERFORMANCE-BASED EDUCATION AND CBC

Performance-Based Education (PBE) is a teaching and learning system that requires actual student demonstrations of learning. All students are held to a standard of performance, and they know what is expected of them from the beginning. Because PBE recognizes that all students learn in different ways and at different speeds, students are encouraged to demonstrate their learning through a variety of means. Students are given multiple opportunities to learn and to demonstrate their learning through multiple assessment strategies.

Performance-Based Education has evolved out of the competency-based education movement of the 1960s. While the DCPS Competency-Based Curriculum (CBC) was originally designed to move students toward the achievement of competencies, unfortunately the actual implementation focused more on isolated skills development.

However, The District of Columbia Public Schools' experience with CBC provides a strong foundation for the successful implementation of Performance-Based Education. CBC, for example, sought performance agreement between behavioral objectives, learning activities and assessment tasks. While PBE seeks that agreement as well, PBE views the key elements of curriculum, assessment and instruction as overlapping. Students are viewed as continually constructing meaning as they learn new things over time. They are assessed on their success in reaching goals agreed upon with their teachers.

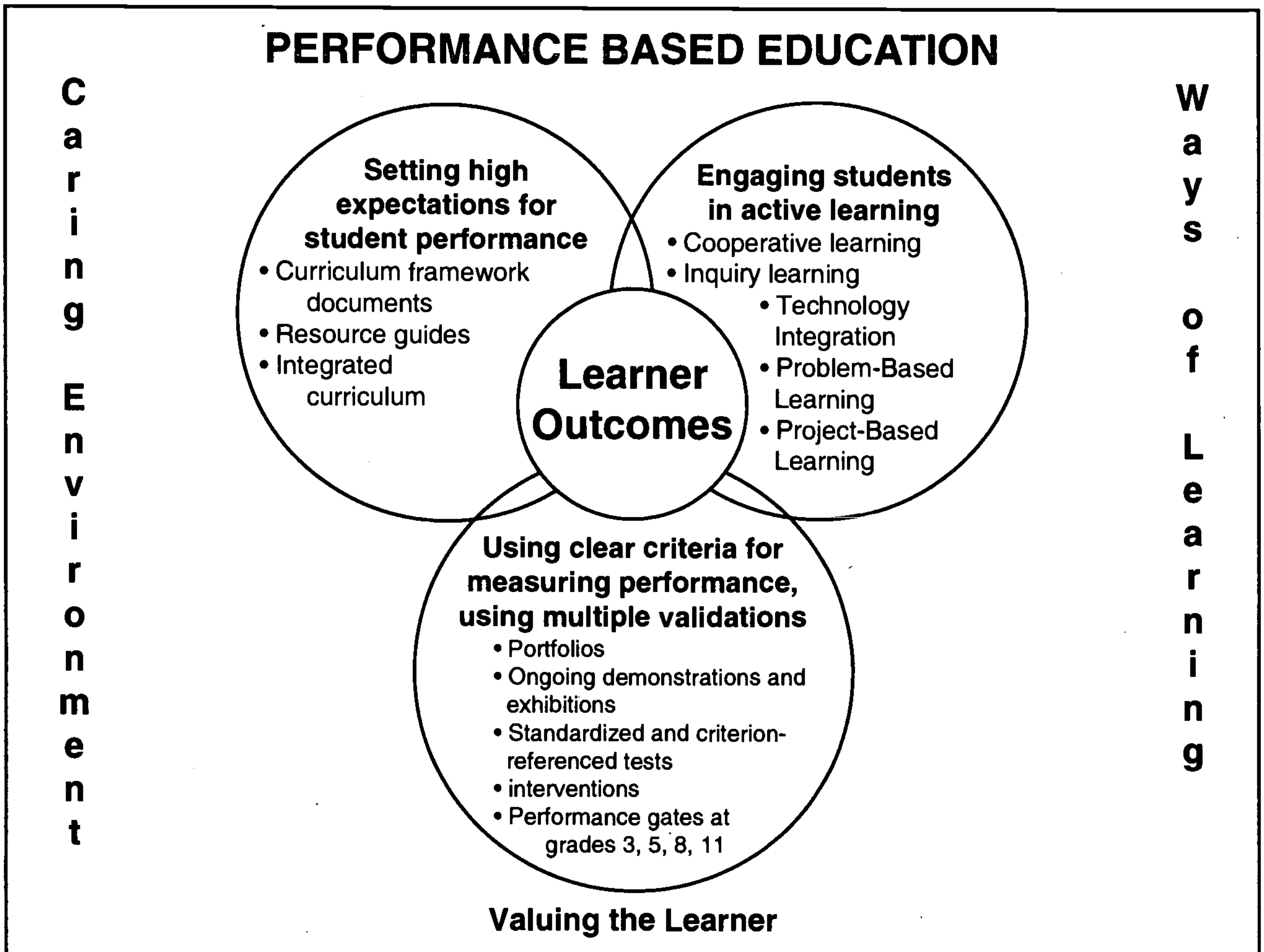

Figure 2

District of Columbia Public Schools

To measure student understanding of content and skills, PBE combines multiple choice tests with performance tasks, such as exhibitions, projects, performances, or papers, that more closely approximate real-life expectations and provide a fuller picture of student learning. Teachers and students assemble portfolios that include samples of student work. Teacher observations of student growth and progress are valued. With a performance-based approach, "performance gates" are established for checking student progress at intervals that correspond to developmental levels, and suggestions are provided for interventions before the "performance gates" are reached.

Figure 2 shows the relationship among the three main elements of the PBE instructional system. These surround the learner outcomes, which are the results of curriculum, assessment, and instruction.

> ***Curriculum*** sets forth rigorous academic standards and high expectations for student performance in curriculum documents such as the framework.
> ***Assessment*** uses multiple types of evidence and explicit criteria to measure student progress.
> ***Instruction***, engages students in active learning.

The performance-based instructional system is set within a context for learning that recognizes the strengths of the urban learner, creates a responsive and caring learning environment, and draws upon multiple dimensions of learning.

THE PURPOSE OF THE CURRICULUM FRAMEWORK

The curriculum framework defines what students must learn in specific subject areas to assure their ultimate success. The purpose of the DCPS curriculum framework is to set these content standards and performance indicators for all students in the school system. The curriculum framework is a powerful tool for teachers to prepare students to reach the learner outcomes.

The curriculum framework also gives clear guidance on what students must demonstrate by the end of grades three, five, eight and eleven so that staff can:
(1) maintain clear focus on the content and foundation skills necessary for student learning and the student's successfull progress toward the learner outcomes; and,
(2) document student and system progress and improvement over time.

Content standards and performance indicators have been carefully selected and aligned with national standards. They will be useful to teachers as they design performance tasks and learning events for students that build upon the students' strengths, experience and previous knowledge.

THE ORGANIZATION OF THE CURRICULUM FRAMEWORK

The Curriculum Framework document has three major sections :

- content standards and technology connections;
- foundation skills and curriculum integration;
- using the document to plan for instruction.

CONTENT STANDARDS AND TECHNOLOGY CONNECTIONS

This section addresses the body of knowledge that students must learn. These standards describe the discipline's key concepts and processes. They come from the recommendations of both national and local subject matter experts and reflect the structure of nationally developed content standards. The section targets broad content areas that teachers are to use as guides for developing instruction. Teachers are expected to create "in depth" learning experiences around content for students, rather than covering a textbook from beginning to end.

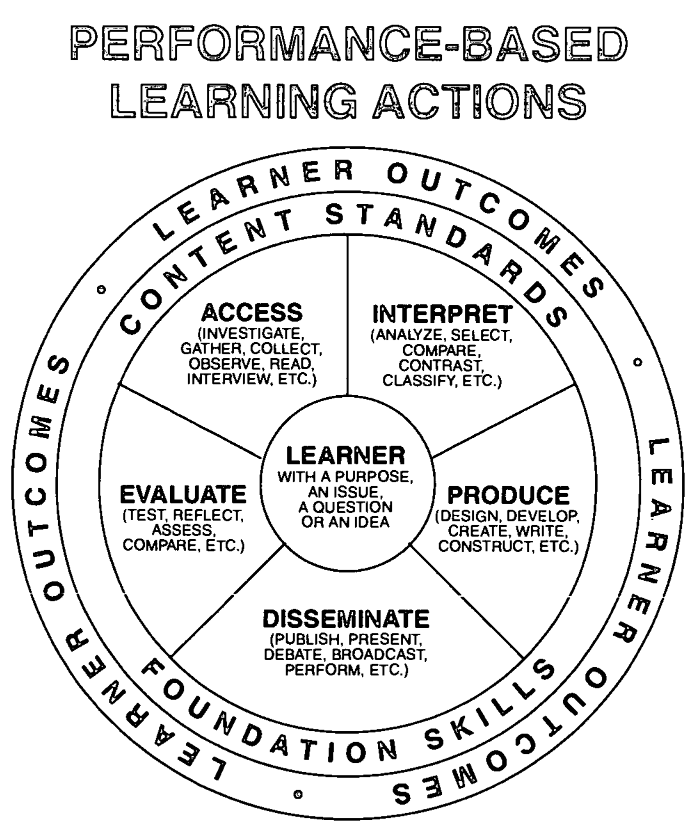

Figure 3

Each content standard has a set of performance indicators that describe what each student should know and be able to do at the developmental levels of grades three, five, eight and eleven. These performance indicators provide teachers, students and parents with a learning focus around which they can plan. They help teachers determine their priorities within the vast knowledge base in each discipline in order to better utilize their instructional time. The performance indicators provide teachers, parents, and community with a clear basis for assessing student progress toward the District's learner outcomes.

This section also describes the system's approach to technology integration and its use in classrooms and learning. Specific examples of how technology should be applied in the content areas are presented.

FOUNDATION SKILLS AND CURRICULUM INTEGRATION

This section presents the skills that all teachers must teach because they represent the building blocks for the attainment of the learner outcomes and the content standards. These skills cross disciplines and are learned and reinforced throughout the curriculum. They can be used to integrate teaching and learning across subject areas. This section also presents different models of interdisciplinary curriculum, as defined by Heidi Hayes Jacobs.

PLANNING FOR INSTRUCTION

The section on using the curriculum framework clarifies the relationship between the curriculum framework document and classroom instruction. The **Learning Actions Wheel** (see Figure 3) is included to show the relationship among the key elements in our PBE curriculum: the learner outcomes, the content standards, the foundation skills, and the learning actions that students must engage in to acquire the necessary knowledge and skills. The wheel portrays how students move to higher levels of thinking as they investigate a particular issue or address an essential question. This section includes a unit planning guide for developing instructional/ assessment units that prepare students for achieving the learner outcomes, content standards, and foundation skills. At the core of the planning process is the development of performance tasks and evaluation criteria that will be used to assess student achievement.

In summary, the Curriculum Framework sets the system wide standard for instruction in the content areas. It guides curriculum development, instruction, assessment and staff development. Together with the Teacher Resource Guide, a companion document, it presents an ambitious and rigorous teaching and learning approach. Combined with professional development, more effective ways of using time, space, community resources, and technology, these curriculum documents represent an exceptional opportunity for professional initiative and renewal with one key goal in mind: the present and future learning success of every student in the District of Columbia Public Schools.

A glossary defines key terms and concepts in Performance-Based Education.

MATHEMATICS

The Mathematics, Science and Technology Framework

This Curriculum Framework focuses upon three separate yet interdependent areas: mathematics, science and technology. Many scholars believe that together these areas comprise science education; they link mathematics, science and technology together because in today's fast–paced, information–filled world of global research and new discoveries, they cannot be separated.

In their book *Science for All Americans* (1989), F. James Rutherford and Andrew Ahlgren describe the need for a more scientifically literate population. They argue that the serious problems people face today are global problems: unchecked population growth in many parts of the world, acid rain, shrinking rain forests, pollution, disease, and scarce resources. What the future holds for all the citizens of the world depends to a large extent on how those problems are addressed and resolved. And that depends on how well people are educated. Rutherford and Ahlgren set forth the following clear rationale for the study of mathematics, science and technology:

- Science will provide people with the knowledge of the biophysical environment and of alternative social behaviors to begin solving global and local problems.
- Science will foster a respect for nature that will inform decisions about the use of technology.
- Problem–solving processes and habits of mind will help people deal with issues in a systematic, logical and independent way.
- Technology will provide some of the tools for dealing with pressing global and local problems.
- An understanding of mathematics, science and technology will enhance the quality of life for all people and inform decision–making that will effect next generations.

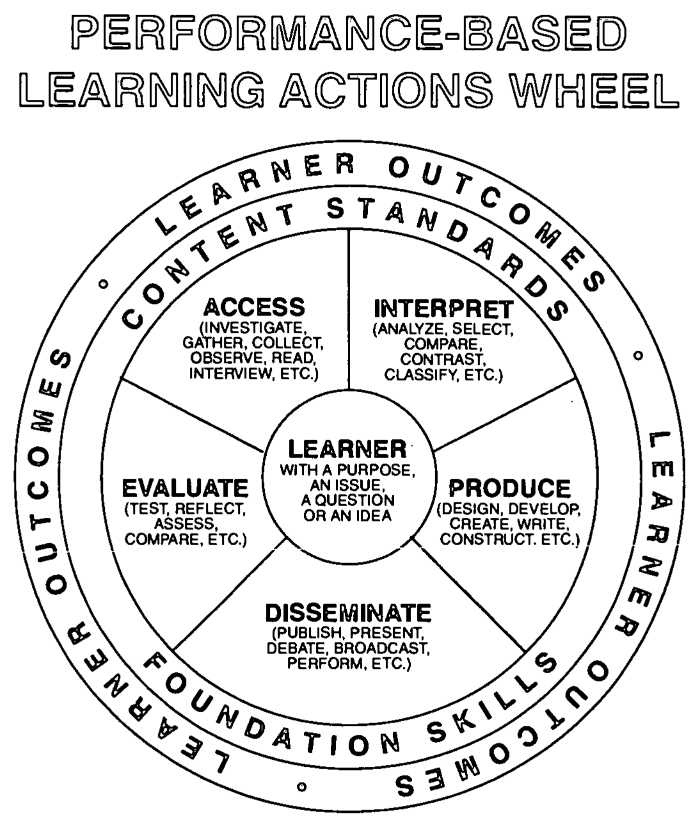

Figure 3

This Mathematics–Science–Technology Curriculum Framework is informed by the National Research Council's (NRC) *Science Standards*, the National Council of Teachers of Mathematics (NCTM) *Curriculum and Evaluation Standards,* and Project 2061. It sets the standards and provides direction for the system's Mathematics–Science–Technology Initiative, which aims to systematically and comprehensively change the teaching of science and mathematics in the District of Columbia Public Schools. It not only serves as a basis for all curriculum and instruction in the classroom, but also sets forth a framework for professional development and training for teachers who have responsibility for instruction in mathematics and science.

In the framework, the disciplines of mathematics and science are treated separately with regard to their content. We realize that technological developments have radically altered the tools used by mathematicians, biologists, medical scientists, physicists and all science professionals. Therefore, the integration of technology into mathematics and science instruction is essential. It reflects a commitment to our students: that they will use computers, calculators, laser disc players and other technologies in their studies. It also reflects a recognition that fields such as engineering, involve the systematic development and application of technology to scientific and mathematical knowledge.

The Framework presents a curriculum for science, mathematics and technology that is for ALL students. At the elementary level, mathematical and scientific thinking are emphasized: acquiring and using strategies to solve problems; recognizing patterns and relationships; and investigating, observing, questioning and drawing conclusions. At the secondary level, as content expands and deepens, so too does the level of scientific and mathematic thinking. Integrated throughout the K–12 continuum is the continued learning about and use of technology to support and enhance learning.

In the next sections, the mathematics and science content standards are presented, along with performance indicators for the achievement of those standards at grades 3, 5, 8 and 11. The section on technology outlines the skills that students should acquire, and makes connections between the technology and the content areas. Mathematics and science teachers have responsibility for assuring that ALL students have an opportunity to learn the content and demonstrate the skills inherent in the standards.

MATHEMATICS

The mathematics standards and student performance indicators in this section are informed by the national standards set by the National Council for Teachers of Mathematics. They broaden the scope of what has been the traditional school mathematics curriculum. Organized under seven standards, the new mathematics content integrates mathematical concepts, principles and applications that prepare students for living and working in the twenty-first century.

Mathematical thinking is an integral part of modern everyday life. Therefore, all students must develop mathematical power. The core curriculum must be sufficiently broad and deep so that each student will have the skills needed for employment or for further study in mathematics and related subject areas. The content standards fall under seven major headings:

- Number Sense and Estimation
  Students interpret the multiple uses and forms of numbers encountered in the real world.

- Numeration Systems
  Students select, perform and justify appropriate methods of calculation, using mental math, paper and pencil operations, calculators or computers to determine if answers are reasonable and/or accurate.

- Measurement
  Students select appropriate tools and units, apply measurement concepts, and communicate measurement-related ideas to solve problems in daily life.

- Algebraic Concepts and Operations
  Students use physical models, equations and graphs to generalize number patterns, and to describe, represent and analyze relationships among quantities.

- Geometry and Spatial Sense
  Students draw inferences and make logical deductions about real world geometric problems and situations.

- Patterns, Relationships and Functions
  Students recognize, extend and form generalizations about patterns; recognize and analyze relationships and model real world phenomena with a variety of functions.

- Probability and Statistics
  Students gather, display, organize, interpret and analyze data to model mathematic situations to determine probability and to make predictions.

These standards are not to be taught as separate entities, but should be integrated instructionally within the classroom at all grade levels.

CONTENT STANDARD: Students interpret the multiple uses and forms of numbers encountered in the real world.

Students must understand numbers if they are to make sense of the way numbers are used in their everyday world. Students learn to represent and model numbers in order to quantify, to identify location, to name and to measure. Students must be able to develop a link between their world and the world of mathematics. At the same time, they must recognize that everyday quantitative situations do not always give exact results and that estimation is an important skill in determining whether results are reasonable.

What a student should know and be able to do by the end of Grade 3:

Students should develop number sense through manipulation of physical objects. They should also recognize that everyday quantitative situations do not always give exact results and that estimation is important in identifying whether or not results are reasonable.

1. Connect number sense and numeration to concrete materials.
2. Make and use estimations with numbers and measures.
3. Apply estimation skills to identify reasonable results.

What a student should know and be able to do by the end of Grade 5:

Students must develop an estimation "mind-set" in which they accept estimation as a legitimate and important part of mathematics. They must also recognize that numbers have multiple representations, and it is important to know why a particular representation is useful in a given setting.

1. Apply estimation in working with quantities, measurements, computation, and problem solving.
2. Recognize when an estimate is appropriate for a situation and apply estimation strategies.
3. Interpret the multiple uses of numbers encountered in the real world.

What a student should know and be able to do by the end of Grade 8:

Through the application of mathematics to other disciplines, students should observe the need for and appropriate use of numbers beyond whole numbers. They should begin to recognize the role of number relationships in developing computational techniques. As they investigate various computational techniques, they should develop an awareness of where and when technology provides an appropriate method of computation.

1. Extend their development of number sense to include all real numbers.

2. Investigate and appreciate the need for numbers beyond the whole numbers.

3. Develop and apply number theory concepts (e.g., primes, factors, multiples) in real-world and mathematical problem situations.

4. Develop, analyze and explain procedures for computation and techniques for estimation.

What a student should know and be able to do by the end of Grade 11:

At the high school level, the concepts of number sense and estimation must be expanded to include the use of discrete mathematics as a powerful representation or modeling tool. Students must become aware of the difference between modeling the physical world via continuous mathematics and modeling the world of information systems and data analysis through finite tools such as graphs and matrices.

1. Convey a thorough understanding of the real number system including the hierarchy of real numbers, the meaning of infinity, ordering, and basic operations.

2. Represent problem situations using discrete structures such as finite graphs, matrices, sequences and recurrence relations.

3. Represent and analyze finite graphs using matrices.

4. Solve enumeration and finite probability problems.

CONTENT STANDARD: Students select, perform and justify appropriate methods of calculation, using mental math, paper and pencil operations, calculators or computers to determine if answers are reasonable and/or accurate.

Students investigate numeration systems and their underlying concepts. The central focus should be to empower students with knowledge of the underlying structure of mathematics. Students should recognize mathematics in real world situations and be able to determine which particular mathematical operation or combination of operations is appropriate to that situation. As they expand their knowledge of operations and explore various methods of computation, they will gradually move from concrete operations to more abstract concepts and operations.

What a student should know and be able to do by the end of Grade 3:

Students should recognize, use, and explain mathematical operations in appropriate and real world applications.

1. Investigate the base ten system by relating, counting, grouping, and discovering place value concepts using concrete materials.

2. Demonstrate algorithms, investigate the relationships, and apply operations with whole numbers.

3. Make mathematical connections between language, symbols and operations.

4. Use manipulatives, role playing, pictures or models to solve problems using the four basic operations.

5. Use models to demonstrate the relationships between fractions, decimals and whole numbers.

6. Use manipulatives and other forms of technology to simulate real life situations that involve fractions and decimals.

7. Demonstrate the relevance of mathematical computations to daily life situations.

What a student should know and be able to do by the end of Grade 5:

As students expand their knowledge of operations with real numbers, they should explore various methods of computation from written to the use of calculators and computers and should determine which method is most appropriate for the given situation.

1. Investigate meanings for whole numbers, fractions and decimals through real world experiences and the use of concrete materials, models, drawings and diagrams.

2. Develop and use comparisons and properties of operations for whole numbers, decimals and fractions.

3. Select and use an appropriate strategy of computing from mental arithmetic, estimation, paper and pencil, calculator and computer methods.

4. Compute using the four basic operations on whole numbers, fractions, and decimals.

What a student should know and be able to do by the end of Grade 8:

By the time students complete middle school they must have built upon their knowledge of numeration systems to include rational numbers and to recognize that rational numbers have multiple representations. In addition, they should also begin to apply rations and proportions to real world problems.

1. Represent and use real numbers in a variety of equivalent forms (integer, fraction, decimal, percent, exponential, and scientific notation) in real world and mathematical problem situations.

2. Apply ratios, proportions, and percents in a wide variety of situations.

3. Investigate and use order relations for whole numbers, fractions, decimals, integers, and rational numbers.

4. Select, use and justify an appropriate method for computing from mental arithmetic, paper and pencil, calculator, and computer methods.

5. Compute with whole numbers, fractions, decimals, integers and rational numbers.

What a student should know and be able to do by the end of Grade 11:

As students approach the mathematical structure inherent in numeration systems from a more abstract perspective, the degree of abstraction or formalism should be consistent with the student's level of mathematical maturity. Students must learn to communicate their concepts of structure to others either orally or in writing.

1. Illustrate that seemingly different mathematical systems may be essentially the same by using physical materials and models to explore fundamental properties of number systems.

2. Compare and contrast the real number system and its various subsystems with regard to their structural characteristics.

3. Develop the complex number system and demonstrate facility with its operations utilizing technology.

4. Develop conjectures and intuitive proofs of properties of number systems.

5. Explain the logic of algebraic procedures.

CONTENT STANDARD: Students select appropriate tools and units, apply measurement concepts, and communicate measurement-related ideas to solve problems in daily life.

Measurement is a useful and practical application of mathematics. Students apply measurement concepts and communicate measurement related ideas. They become aware of the importance of standard units and common measurement systems. They must also be able to determine when an estimate is sufficient and what degree of accuracy is required in a given situation.

What a student should know and be able to do by the end of Grade 3:

Classroom activities should focus on measuring real objects, making objects of given sizes, and estimating measurements. Initial explorations should involve nonstandard units to which students can easily relate, so they will develop some basic understanding of units, and begin to recognize the necessity of standard units in order to communicate effectively.

1. Estimate, measure and compare measurable attributes of objects.

2. Investigate nonstandard and standard units to measure perimeter, area, volume, and weight.

3. Determine the appropriate unit for measurement of time, temperature, and money.

4. Make and use measurements to solve problems in everyday situations.

What a student should know and be able to do by the end of Grade 5:

Measurement concepts such as area, perimeter, time, weight, etc. introduced in earlier grades should be extended and applied to exploring and solving problems, and investigating other areas of mathematics.

1. Investigate the concepts of length, capacity, weight, perimeter, area, volume, time, temperature, and angle measurement.

2. Utilize standard and nonstandard systems of measurement.

3. Estimate, construct, and use measurements for description and comparison.

4. Select appropriate units and tools to measure to the degree of accuracy required in a particular situation.

5. Connect measurement with other aspects of mathematics and with other disciplines.

What a student should know and be able to do by the end of Grade 8:

As students progress through middle school, they should develop more efficient measurement methods and apply formulas to two and three-dimensional problems. In addition, they should recognize when an estimate is sufficient and what degree of accuracy is required in a given situation.

1. Estimate and measure, using appropriate units and tools to describe and compare phenomena.

2. Extend understanding of the concepts of perimeter, area, volume, capacity, weight, and mass.

3. Develop and explains the concepts of rates and other derived and indirect measurements.

4. Develop formulas and procedures for determining measures to solve real world problems.

5. Use computation, estimation and proportions to solve problems.

What a student should know and be able to do by the end of Grade 11:

Students need to investigate situations in which measurement plays an important role in everyday life. They need to work with multiple units of measurement and to determine accuracy and acceptable degree of error.

1. Choose appropriate techniques and tools to measure quantities and apply the knowledge of the relationship among precision, accuracy and error of measurement.

2. Convert measurement units from one form to another and carry out calculations.

3. Use rate to deal with practical measurement tasks.

4. Solve real world problems involving length, area and volume, using ratios and proportions.

5. Use suitable methods of approximation to find areas and volumes of irregular shapes.

6. Investigate calculus processes involving length, area and volume.

7. Use trigonometric ratios to solve problems in two and three dimensions.

CONTENT STANDARD: Students use physical models, equations and graphs to generalize number patterns, and to describe, represent and analyze relationships among variable quantities.

Algebra is more than symbolic manipulation of numbers and variables; it is a means of representation and a tool for problem solving. As early as elementary school, students should develop a sense of using objects to represent values. Throughout the curriculum, emphasis is placed on this conceptual understanding in addition to facility with symbolic manipulation. Students should be given opportunities to explore algebraic concepts informally to bridge the gap between arithmetic and more formal study of algebra. These explorations involve the use of models, tables, graphs and other mathematical representations to describe physical patterns. Building upon their informal algebra experiences, students will begin to apply algebraic methods to the solution of real world problems and to appreciate the power of mathematical abstraction and symbolism.

What a student should know and be able to do by the end of Grade 3:

Students should begin to form an understanding of the concept of variables through the use of concrete objects to represent quantities or mathematical relationships. Emphasis should be placed on concepts rather than vocabulary or specific skills.

1. Create number stories using manipulatives.
2. Use a symbol to stand for a value.
3. Use concrete materials to create algebraic expressions.
4. Use open sentences to express mathematical relationships.

What a student should know and be able to do by the end of Grade 5:

As students begin to bridge the gap between arithmetic and a more formal study of algebra, they must be given opportunities to explore algebraic concepts informally. These explorations should emphasize using physical models, tables, graphs and other mathematical representations to describe observed physical patterns. Through these explorations students should gain confidence in their ability to abstract relationships from contextual information.

1. Use problem solving strategies to find the values of variables.
2. Explore the concepts of variables, expressions, equations, and inequalities.
3. Use patterns and relationships to develop and analyze algorithms.

4. Explore the use of variables and open sentences to express relationships.

5. Apply algebraic methods to solve a variety of real world and mathematical problems.

6. Represent numerical relationships using graphs.

What a student should know and be able to do by the end of Grade 8:

During middle school, students should build on their informal algebra experiences and apply algebraic methods to the solution of real world problems. They should develop confidence in solving linear equations by formal methods as well as through the use of technology.

1. Apply the concepts of variable expression and equation.

2. Represent situations and number patterns with tables, graphs, rules, and equations and explore the interrelationship of these representations.

3. Analyze tables and graphs to identify properties and relationships.

4. Develop confidence in solving linear equations using concrete, informal, and formal methods.

5. Investigate inequalities and nonlinear equations informally and through the use of technology.

6. Apply algebraic methods to solve problems based on practical applications.

What a student should know and be able to do by the end of Grade 11:

Students build on their previous informal exploration of algebraic concepts to appreciate the power of mathematical abstraction and symbolism. Through the use of technology, students can experience a richer set of algebra experiences that allows them to investigate algebraic models at a conceptual level through representation in terms of graphs, tables, polynomials and matrices.

1. Represent situations that involve variable quantities with expressions, equations, inequalities, matrices, and other discrete structures such as sequences.

2. Use tables and graphs as tools to interpret expressions, equations, and inequalities, using technology whenever appropriate.

3. Evaluate formulas and expressions to solve applied problems.

4. Operate on expressions and matrices and solve equations, inequalities, and systems of equations.

5. Read, translate and solve real world problems using mathematical language and symbols.

CONTENT STANDARD: Students draw inferences and make logical deductions about real world geometric problems and situations.

Through the study of geometry, students develop spatial intuitions and an understanding of geometric concepts. Students learn to solve problems that require observing, describing, analyzing, and testing physical phenomena. They also learn to recognize, transform and construct relationships between geometric figures. Geometric models help students make abstract situations more easily understood.

What a student should know and be able to do by the end of Grade 3:

Students should use manipulative materials to develop geometric concepts and spatial sense. They should first learn to recognize whole shapes and then analyze relevant properties of the shapes.

1. Investigate, identify, classify, and describe the three-dimensional world in which we live.
2. Use spatial sense to solve geometric problems.
3. Investigate and predict the results of combining, subdividing, changing, and transforming shapes.

What a student should know and be able to do by the end of Grade 5:

Students should continue to use manipulatives as the basis for their development of geometric and spatial sense. Small group work encourages the ability to use mathematical language to describe real phenomena.

1. Apply plane and solid geometry vocabulary and ideas to real life situations.
2. Relate geometric ideas to number and measurement ideas.
3. Model and construct geometric figures with manipulative materials.
4. Identify, describe, classify, and compare geometric shapes, figures and models.
5. Develop spatial sense by learning to visualize and represent geometric figures.
6. Explore and predict the results of combining, partitioning, and changing shapes, figures, and models.

What a student should know and be able to do by the end of Grade 8:

Students should use geometric models to analyze and solve problems and recognize that geometric interpretations and models can help make an abstract situation more easily understood.

1. Identify, describe, compare, and classify geometric figures.
2. Visualize and represent geometric figures with special attention to developing spatial sense.
3. Explore transformations of geometric figures.
4. Investigate and solve problems using geometric models.
5. Apply geometric properties and relationships to solve problems.
6. Develop an understanding of geometry as a means of describing the physical world.

What a student should know and be able to do by the end of Grade 11:

At the high school level, students acquire a deeper understanding of shapes and their properties, with an emphasis on their wide applicability to the real world. Students should have opportunities to visualize and work with three-dimensional figures to develop spatial sense fundamental to everyday life and many careers. The use of models and actual objects assist in the development of geometric intuition, which provides a base for working with more abstract ideas.

1. Represent problem situations with geometric models and apply geometric properties related to those models.
2. Classify figures in terms of congruence and similarity and apply those relationships.
3. Deduce properties and relationships between figures from given assumptions.
4. Translate between geometric and algebraic representations.
5. Deduce properties of figures using transformations and coordinates.
6. Identify congruent and similar figures using transformations.
7. Analyze properties of Euclidean transformations and relate translations to vectors.
8. Apply trigonometry to problem situations involving triangles.
9. Explore periodic natural phenomena using the sine and cosine functions.

CONTENT STANDARD: Students recognize, extend and form generalizations about patterns; recognize and analyze relationships and model real world phenomena with a variety of functions.

Mathematics has been characterized as the language or science of patterns. Relating patterns in numbers, geometry, and measurement allows students to make connections between mathematical topics and instills an awareness of the beauty of mathematics. Pattern recognition and the forming of generalizations are effective problem solving tools, as well, and provide the basis for developing the concept of functions. The study of patterns, functions and relationships helps students to recognize that different representations model real-world relationships in nature, language, and history.

What a student should know and be able to do by the end of Grade 3:

Students should be encouraged to look for patterns and relationships as a means of classifying and organizing data. Observing varied representations of a pattern or relationship helps students identify its properties and develop an intuitive idea of functional relationships.

1. Investigate, describe, sort, classify, and identify objects and patterns using one or more attributes.

2. Observe the properties of objects to determine relationships and make generalizations.

3. Describe, extend, create, and record patterns.

4. Investigate the connections among mathematical topics through relationships and patterns in numbers, geometry, and measurement.

5. Determine how mathematics applies to the world through relationships and patterns in numbers, geometry, and measurement.

What a student should know and be able to do by the end of Grade 5:

At this level, work with patterns should still be informal and relatively free of symbolic representation. Students should have the opportunity to generalize and describe patterns and relationships in both numeric and geometric settings. Exploration of patterns should help students build mathematical power and instill in them an awareness of the beauty of mathematics.

1. Recognize and create patterns based upon the attributes of objects or numbers and validate thinking by using oral and written communication.

2. Recognize and relate patterns based upon the composition and structure of other disciplines (e.g., meter in music, rhythm in poetry, tessellations).

3. Observe, make, and test conjectures by creating examples or constructing counter-examples.

4. Use patterns and functions to solve problems and to analyze mathematical situations.

What a student should know and be able to do by the end of Grade 8:

During the middle school years, the study of patterns should begin to shift from informal recognition to a more formal exploration of functions. Students should recognize the importance of using tables, graphs, expressions or equations, and verbal descriptions to generalize and describe patterns and relationships. They also should begin to investigate the dynamic nature of functions in which a change in one variable results in the change of another.

1. Describe, extend, analyze, and create a wide variety of patterns.

2. Describe and represent relationships with tables, graphs and rules.

3. Generalize patterns using words or symbolic notation.

4. Analyze functional relationships to explain how a change in one quantity results in a change in another.

5. Make, test, and utilize generalizations about given information as a means of solving problems and of judging the validity of arguments.

6. Use patterns and functions to represent and solve problems.

7. Utilize technology to explore patterns.

What a student should know and be able to do by the end of Grade11:

At the high school level, the study of patterns and relationships evolves predominantly into the study of functions. Students need to recognize that functions can be represented in a variety of ways, such as a written statement, an algebraic formula, a table of values or a graph, and that these representations enable us to model actual relationships.

1. Represent and analyze relationships using tables, rules, equations and graphs.

2. Translate among tabular, symbolic, and graphical representations of functions.

3. Model real phenomena with a variety of functions.

4. Illustrate that a variety of problem situations can be modeled by the same type of function.

5. Investigate informally calculus concepts from both a graphical and a numerical perspective.

6. Analyze the effects of parameter changes on the graphs of functions through the use of technology.

CONTENT STANDARD: Students gather, display, organize, interpret and analyze data to model mathematic situations to determine probability and to make predictions.

Knowledge of the concepts of probability and statistics is essential to being an informed citizen. With society's expanding use of data for prediction and decision making it is important that students develop an awareness of the concepts and processes used in analyzing data. Students should recognize that data comes in many forms and that collecting, organizing and displaying data is a powerful informational tool. They should have experiences using technology to present and organize data. Students use their knowledge of probability to solve problems through simulation and modeling.

What a student should know and be able to do by the end of Grade 3:

At this level, activities should be of an investigative or exploratory nature. Students should use actual objects to investigate situations involving chance. They also need to recognize that data comes in many forms and that collecting, organizing, and displaying data can be done in many ways.

1. Collect, organize, describe, display, and interpret data.

2. Perform, predict, and discuss the outcomes of probability experiments.

3. Use data to make decisions and predictions.

4. Construct, read, and interpret charts, tables, and graphs.

What a student should know and be able to do by the end of Grade 5:

Students should actively explore situations by experimentation and simulation. They should use charts, graphs, and plots to reinforce their interpretation of collected data and make predictions.

1. Recognize familiar situations that involve change and make simple predictions.

2. Use simulations and experiments to determine probabilities (including actual experiments as well as computer generated ones).

3. Formulate and solve problems using charts, tables, and graphs.

4. Collect, organize, discuss, describe, and make predictions with data.

5. Construct, read, and interpret graphic representations of data.

What a student should know and be able to do by the end of Grade 8:

In order to see how everyday predictions are based on probability, students should use their knowledge of probability to solve problems through simulation or modeling. They should build an awareness of the difference between experimental results and mathematical probability. As they interpret tables and graphs, they should be able to discuss the message conveyed and discuss how changes in the data or in the method of collection might affect the predictions.

1. Systematically collect, organize, and describe data.
2. Construct, read and interpret tables, charts, and graphs.
3. Make inferences and convincing arguments that are based on data analysis.
4. Evaluate arguments that are based on data analysis.
5. Use statistical methods for decision making.
6. Model situations by devising and carrying out experiments or simulations to determine probabilities.
7. Model situations by constructing a sample space to determine probabilities.
8. Use a probability model to compare experimental results with mathematical expectations.
9. Make predictions and evaluate arguments that are based on analysis of data resulting from experimental or theoretical probability experiments.
10. Interpret data using measures of central tendency.
11. Become aware of the pervasive use of probability in the real world.
12. Understand sampling and recognize its role in statistical claims.
13. Design a statistical experiment to study a problem, conduct an experiment, and interpret and communicate outcomes.

What a student should know and be able to do by the end of Grade 11:

The study of probability and statistics in grades 9 to 11 should build upon the methods of exploratory data analysis from the elementary and middle grades. Students should be encouraged to apply statistical tools to other academic disciplines and recognize that statistics plays an important role in bridging the gap between the exactness of other topics in mathematics and the qualitative nature of a world which is heavily dependent on subjective opinion.

1. Explore, compare, and make inferences from single variable data sets by constructing charts, tables, and graphs, including stem and leaf and box plots.

2. Summarize and make inferences about single-variable data by applying measures of central tendency, variability, and correlation.

3. Look for association in two variable data by constructing and analyzing fitted lines and smoothing over time.

4. Recognize the role of sampling in statistical claims as part of designing a statistical experiment to study a problem, conducting an experiment and interpreting and communicating outcomes.

5. Compare experimental and theoretical probability and estimate probabilities from actual data.

6. Use experimental and theoretical probability to represent and solve problems involving uncertainty.

7. Create and interpret discrete probability distributions and describe the normal curve and use its properties to answer questions about sets of data that are assumed to be normally distributed.

SCIENCE

SCIENCE

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SCIENCE

The science standards and student performance indicators in this section are informed by Project 2061, *Science for All Americans*, and *Benchmarks for Science Literacy* (American Association for the Advancement of Science). These standards are also based on the draft *National Science Standards* developed by the National Research Council of the National Academy of Sciences and *Scope, Sequence and Coordination* developed by the National Science Teachers Association. The content standards that make up the science program fall under the following headings:

- Scientific Inquiry
  Student use the scientific method to ask and answer questions about the world.

- Life Sciences
  Students observe and investigate the characteristics of living things and explain their similarity, diversity, interrelationship, and classifications

- Earth Sciences
  Students understand the origin, history, structure, and functions of the geospheres and how processes and interactions result in changes that shape the Earth's features. They describe weather patterns and changes and their impact on living things.

- Physical Sciences: Energy
  Students identify energy sources and transformation and apply their know-ledge of the fundamental principals of force and motion to explore the world of nature.

- Physical Sciences: Matter
  Students describe the structure of matter and the physical and chemical changes it undergoes.

- Space Sciences
  Students examine the origin and evolution of the universe, the solar system and the earth's place and important within the cosmic context.

- Systems
  Students acquire an understanding of the basic concepts of systems and their uses in explaining phenomena within the context of science and technology.

The content covered in the standards is not meant to be exhaustive. It represents a shift from too much content treated superficially to more important content in greater depth.

PERFORMANCE-BASED LEARNING ACTIONS WHEEL

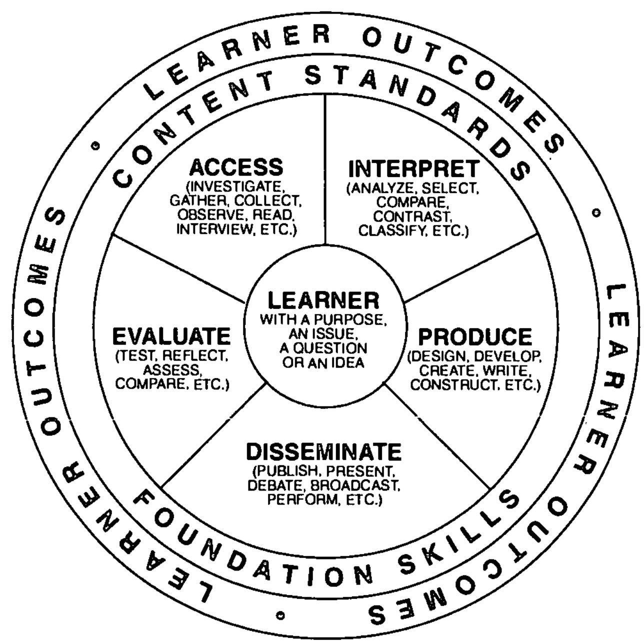


Figure 3

CONTENT STANDARD: Students use the scientific method to ask and answer questions about the world.

Students learn that science places a strong emphasis on applying scientific methods to learning about the world. Students develop the intellectual and practical skills that allow them to explore the world of science and develop a fuller understanding of scientific phenomena and the procedures of scientific exploration and investigation. These skills are used by scientists in pursuing investigations, explaining results and predicting outcomes. These skills are best learned in authentic situations.

What a student should know and be able to do by the end of Grade 3:

Students engage in scientific inquiry by collecting things, categorizing them, conducting simple experiments, asking questions, making observations, and reaching conclusions.

1. Use their senses to observe familiar materials and events in their surroundings.
2. Describe and communicate their observations.
3. Plan and conduct simple investigations to answer questions of the how, why, and what if variety.
4. Select and use simple instruments to enhance observations of objects and events.
5. Identify and describe simple variables that change over time.
6. Construct reasonable explanations based on their observations and data.
7. Use drawings, graphs and written descriptions to present the results of their investigations and explanations.

What a student should know and be able to do by the end of Grade 5:

As they increase their knowledge of scientific phenomena, students develop skill in using the basic processes of scientific inquiry by observing, describing, ordering, inferring, comparing, measuring, classifying, predicting, formulating questions, and usING data to justify conclusions.

1. Ask questions in a form which can be investigated.
2. Plan and conduct an investigation.
3. Obtain and interpret information by using their senses, measuring tools, and instruments to generate results in repeated investigations.
4. Select and use a range of appropriate tools to quantify observations of physical quantities.

5. Construct explanations and exploratory models to initiate new investigations.

6. Summarize and interpret data using drawings, graphs and written descriptions.

7. Communicate experimental procedures, observations, and explanations.

What a student should know and be able to do by the end of Grade 8:

As students move into middle school and junior high school, they should use more complex integrated processes of scientific inquiry: formulating hypotheses, controlling variables, collecting and interpreting data. Scientific tools such as microscopes, balances and other instruments facilitate inquiry and problem-solving strategies.

1. Develop and refine questions using ideas that lead to the formulation of a testable hypothesis.

2. Devise strategies for testing a hypothesis.

3. Identify and manipulate independent variables and control other variables in an investigation.

4. Select appropriate methods of recording data.

5. Compare results of an investigation with others, test for discrepant events or results and propose alternative explanations.

6. Perform an experiment to explain a theory, concept or model and use the results to demonstrate a clear understanding of the ideas that led to the theory, concept, or model.

7. Communicate results of an investigation, incorporating background material from a variety of secondary sources.

What a student should know and be able to do by the end of Grade 11:

The laboratory science courses at the senior high school level should synthesize the use of all the processes of scientific inquiry into a set of investigative skills which can be used in the life-long pursuit of solving problems.

1. Develop an investigation, formulating and sequencing a set of hypotheses to test.

2. Distinguish between relevant and extraneous observations and between observations and inferences.

3. Plan a range of exploratory techniques which employ a variety of sources of information.

4. Formulate additional testable hypotheses supported by the knowledge and understanding generated from an investigation.

5. Generate strategies to produce more accurate, reliable, and precise results in an investigation.

6. Present results persuasively to a variety of audiences.

CONTENT STANDARD: Students observe and investigate the characteristics of living things and explain their similarity, diversity, interrelationship, and classification.

Students develop concepts about living things: how many different species there are, what they are like, where they live, how they relate to each other and how they behave. They learn how to answer these and many more questions about the organisms that inhabit the earth. They develop the concepts, principles, and theories that enable people to better understand the living environment.

What a student should know and be able to do by the end of Grade 3:

Students should investigate different kinds of plants and animals, including weeds, aquatic plants, insects, worms, and amphibians. They should develop knowledge and understanding of the diversity of, and relationships among, living systems.

1. Observe and describe similarities and differences among living things.
2. Observe and describe variations among individuals of the same kind.
3. Use observable features to sort living things into broad categories.
4. Recognize that some traits of living things are inherited while others are learned or acquired.
5. Observe and describe how the structures of living things are adapted to the functions they perform.
6. Describe the major stages in the human life cycle.

What a student should know and be able to do by the end of Grade 5:

Students should explore how various organisms satisfy their needs in the environments in which they are typically found. Students examine the survival needs of different organisms and consider how the conditions in particular habitats can limit the kinds of living things that can survive. Studies of interactions among organisms within an environment should start with relationships that can be observed directly by the student. The use of nature films and tapes can provide observations of diversity of life in different habitats.

1. Describe the conditions needed to sustain life.
2. Describe the levels of organization in organisms (cells, tissues, organs, and systems).
3. Identify features of organisms which enable them to survive in the conditions where they normally live.

4. Explore and analyze the relationship among physical factors of a locality, including seasonal and daily changes, and the species of plants and animals that live there.

5. Identify and explore diversity in the natural world and the behaviors and conditions necessary for survival.

6. Provide examples of the interdependence of plants and animals.

What a student should know and be able to do by the end of Grade 8:

Students should develop a knowledge and understanding of the organization of living things and the processes which characterize their survival and reproduction. They should be guided from specific examples of the interdependency of organisms to a more systematic view of the kinds of interactions that take place among the organisms.

1. Explain the functions of an organism's major systems.

2. Describe the relationships among energy availability, stability, and the evolution of living systems.

3. Relate the patterns of reproduction and development to inheritance and environment in living systems.

4. Provide examples of adaptations, behavior, and rates and patterns of change in living systems.

What a student should know and be able to do by the end of Grade 11:

Students should expand their understanding of the processes of living systems to include an understanding of their contribution to maintaining the internal environment of living systems. They should enhance their understanding of the basic mechanisms of inheritance, selection, and evolution. They should understand the structure of DNA and how it provides continuity from generation to generation.

1. Explain the biochemical processes in living organisms and how the basic life functions contribute to maintaining their internal environment.

2. Demonstrate how environmental factors can be changed to enhance photosynthesis.

3. Compare and contrast Mendelian principles of heredity and the chromosome theory of inheritance.

4. Explain the relationships among variation, natural selection, and reproductive success in organisms and their significance for evolution.

5. Relate population growth and decline of living systems to the availability of environmental resources.

6. Illustrate how materials for growth and energy are transferred through an ecosystem.

CONTENT STANDARD: Students understand the origin, history, structure, and functions of the geospheres and how processes and interactions result in changes that shape the Earth's features. They describe weather patterns and changes and their impact on living things.

In the study of Earth Sciences, students learn that the biosphere extends from the upper layers of the Earth's crust and the deepest part of the ocean to a few thousand meters into the atmosphere. It is the area in which living things exist. It is a complex system where the struggle for survival is played out by millions of diverse species, including humankind. Understanding the relationships among people, other organisms, and the environment helps students to take responsibility for the environment. The study of geology and meteorology and its effects on living things demonstrates the relationship between the living and non-living worlds. Students observe patterns, relationships, and processes in nature. They explore the processes and forces of nature and apply the skills of classification, observation, comparison and adaptation to learn how humans have affected the environment and the environment has affected humans.

What a student should know and be able to do by the end of Grade 3:

Students should develop the knowledge and skills needed to observe and explore their neighborhoods. Local plants and minerals should be collected and examined to identify simple similarities and differences. Students should observe how plants and animals depend upon their environment, gaining an understanding of the concept of habitat. They should observe and record weather changes, recognize patterns to these changes and relate these changes in living and non-living things in their environment.

1. Explore and describe features of the local environment that make it similar and dissimilar to other environments.
2. Examine, investigate and determine similarities and differences among various rocks and minerals from the local environment.
3. Provide examples of the interdependence of plants, animals and environment.
4. Give examples of how humans and other animals cause beneficial or harmful changes in the environment.
5. Define, describe and give examples of habitats and shelters.
6. Record and compile observable weather conditions and search for simple relationships and patterns in the weather over varying time intervals.
7. Recognize the existence of climatic regions and associate them with characteristic plants, animals, rocks and minerals.

What a student should know and be able to do by the end of Grade 5:

Students investigate land forms and layering evidence of geological change over time. They study local long-term weather conditions and seasonal cycles to illustrate how changing conditions affect processes such as evaporation and condensation. Students understand the interdependence of organisms as they investigate their environment.

1. Design and use models to identify and describe the characteristics which differentiate the Earth's composition and changes over time.

2. Develop and use a system to collect and classify soils.

3. Explain how processes on Earth such as the movement of plates and the flow of air and water are driven by heat energy.

4. Investigate and relate various cycles of weather to environmental conditions.

5. Investigate the factors which affect meteorological processes such as evaporation and condensation and build models which demonstrate the relationship between these processes and weather.

6. Analyze the interdependence of organisms living in an ecosystem.

7. Illustrate food chains and the recycling of materials in nature.

8. Compare characteristics of dominant plants and animals in the major biomes of the world.

What a student should know and be able to do by the end of Grade 8:

Students should observe and categorize rocks of different types. Students should understand how natural forces and energy sources have affected living and non-living things and how humans have adapted to various natural forces. Students construct several basic weather measurement instruments and use these and other technologies to collect data and make weather predictions. Students investigate the relationships between changes in weather and changes in living systems.

1. Examine the properties of various minerals to classify them as being sedimentary, metamorphic or igneous. Explain the processes by which they were formed and are recycled.

2. Provide examples of natural disturbances to the environment and their consequences.

3. Provide examples of how man has adapted to the forces of nature and used technology to enhance his ability to deal with these forces. (See also Life Sciences.)

4. Design and construct devices to measure air temperature, pressure, speed and direction.

5. Select and use instruments and technologies to predict short and long term weather conditions.

6. Investigate relationships that exist between the behavior of organisms and their environment.

7. Compare traits of the dominant organisms characteristic of the four major geological eras.

8. Research and relate evidence provided by fossils that indicates many forms of life have become extinct due to changes in the environment.

What a student should know and be able to do by the end of Grade 11:

Students should develop their knowledge and understanding of the structures and features of the Earth, researching and investigating the relationships between its composition and the occurrence of natural disasters. Students should build a coherent and comprehensive concept of an ecosystem and the factors that affect its population levels, equilibrium, diversity and succession. They investigate the relationship between human activity and depletion of resources.

1. Observe, collect data, and construct models to show that the Earth's interior is composed of layers of materials which differ in composition and density.

2. Use the theory of plate tectonics to explain some major geological features on the Earth's surface.

3. Compare zones of active crust (volcanoes and earthquakes) to patterns in the distribution of the Earth's major surface features.

4. Explore processes that occur within the Earth's crust and interior and describe current technology available to monitor and predict these processes.

5. Explain how changes in the atmosphere cause weather phenomena.

6. Investigate the subtleties of ecological balance and how man's choices influence this balance.

7. Evaluate the positive and negative effects of artificial ecosystems.

8. Provide examples of human activity that can result in major changes in the biosphere.

CONTENT STANDARD: Students identify energy sources and transformations and apply their knowledge of the fundamental principles of force and motion to explore the world of nature.

Students learn that energy has many forms and comes from many sources so it is important to focus on the observable qualities related to energy. Events in the universe involve transformations of energy forms, and interactions between matter and energy. In a closed system, the total amount of matter and energy does not change; however, everything in the universe moves according to certain principles. Students learn that all physical events require the transfer of energy from one form to another and from one object to another, and that not all energy is useful energy.

What a student should know and be able to do by the end of Grade 3:

Students benefit from discussions about energy, energy needs, and energy sources, including the sun and food. They learn, for example, that moving things require energy.

1. Observe and describe common forms of energy.
2. Conduct an investigation which demonstrates that the sun is a source of energy.
3. Observe and explain energy changes in common chemical reactions.
4. Observe and describe objects in motion and the relation between energy and motion.
5. Use simple machines to move an object and discuss the relationship between energy and work.
6. Demonstrate that vibrating objects produce sound and discuss the relationship between energy and sound.

What a student should know and be able to do by the end of Grade 5:

Students build on their knowledge of energy sources and explore in greater detail the forms and transformations of energy.

1. Design and conduct investigations which demonstrate the relationship between kinetic and potential energy.
2. Explore the sources and transformations of energy used everyday.

3. Observe and apply the principle of the conservation of energy.

4. Design and perform investigations which demonstrate that some materials conduct heat better than others.

5. Design and perform investigations on the effects of energy on plant growth.

6. Observe and describe the effects of common forces such as gravity, electrical charge, and magnetism on objects.

What a student should know and be able to do by the end of Grade 8:

At this level, students test theories about the ways objects acquire or expend energy. They explore the causes of motion, construct and use simple machines to demonstrate uses of force, and examine electricity, magnetism, heat, sound, and light.

1. Observe and apply the principle of the conservation of energy.

2. Design and perform investigations that demonstrate the properties of light, heat, sound, electricity and magnetism.

3. Design and perform investigations to show how energy is used by the body.

4. Demonstrate changes in the speed and direction of objects and the effects of friction on the motion of objects.

5. Construct and use simple machines to demonstrate the use of forces.

What a student should know and be able to do by the end of Grade 11:

The study of energy becomes more complex and quantitative. Students investigate atomic and molecular structures and their relationship to radiant energy. Energy of fission and fusion should be introduced. Students calculate mechanical equivalents of heat and elasticity, gravitational potential, kinetic and rotational energies. They measure temperature and calculate heat flow and latent heat. They relate electrical energy and power and electrical and thermal energy.

1. Design and conduct a study which compares and contrasts the different forms of energy and energy transformations.

2. Measure potential and kinetic energies to explain the conservation of energy.

3. Compare relationships among and applications of origin, form and speed, as well as the nature and properties of various wave forms in nature.

4. Apply the laws of thermodynamics to the quantitative relationships between heat and other forms of energy.

5. Relate temperature to molecular motion, and apply gas laws to predict the volume and pressure change of a gas.

6. Demonstrate an understanding of the principles of calorimetry.

7. Investigate motion in terms of velocity and acceleration, the causes of motion, equilibrium, and momentum.

8. Use the laws of electricity to design and build electrical systems and to solve simple DC and AC circuit problems.

CONTENT STANDARD: Students describe the structure of matter and the physical and chemical changes it undergoes.

Students learn that matter is anything that has mass, takes up space, and possesses inertia. Students study the structure of matter and the physical and chemical properties of matter. This includes particulate and quantum models of matter, atomic structure, molecules and bonding. Students investigate how matter combines and responds to changes in variables such as temperature and pressure.

What a student should know and be able to do by the end of Grade 3:

Students explore and investigate the observable properties of many materials and learn how to categorize matter according to its properties. They explore and describe how matter responds to simple changes such as mixing, bending, heating, freezing, scratching and dissolving.

1. Observe, describe, compare, and group objects in terms of observable physical properties (e.g. color, size, shape, etc.).
2. Observe, compare and contrast the common states of matter (e.g. solid, liquid, gas, plasma).
3. Demonstrate the proper use of tools, such as scales, thermometers, masses, and magnifying glasses to observe, collect data, and describe matter.
4. Conduct experiments to show changes in the properties of substances.
5. Show that matter occupies space and has weight.

What a student should know and be able to do by the end of Grade 5:

The study of matter should become more systematic and quantitative. Students design simple experiments to explore, measure, collect data and present findings about the more complex properties of matter, such as buoyancy, density, heat flow, etc.

1. Demonstrate the proper use of laboratory equipment and tools to observe and measure properties and interactions of matter.
2. Design and conduct experiments to examine the properties of different materials.
3. Design and conduct experiments to explore and investigate simple aspects of the laws of conservation of matter (mass, volume, ...).

4. Research the origin of everyday materials.

5. Design objects for specific uses and purposes.

What a student should know and be able to do by the end of Grade 8:

By this time, students have a grasp of the general properties of matter and know that most substances can exist in different states or phases. The effect of temperature on the state of matter should be investigated. Concepts related to the properties of elements, molecules, mixtures, compounds and the conservation of matter should be developed at this level.

1. Design and conduct an experiment to explain the basic structure of the atom and its behavior when substances combine chemically.

2. Distinguish between physical and chemical properties of matter.

3. Use the Periodic Table to describe similarities in the chemical and physical properties of substances.

4. Relate chemical and physical change to events such as the water cycle, the carbon cycle, photosynthesis, and plant growth.

5. Use physical processes to separate mixtures and compounds.

6. Observe and apply the principle of the conservation of mass.

7. Use the kinetic molecular theory to explain matter phase changes.

What a student should know and be able to do by the end of Grade 11:

Students continue to investigate the complexities of matter by moving at the atomic and nuclear level. The concepts of the structure of matter and the forces that mediate that structure from chemical and nuclear bonds to gravitational and electromagnetic forces should be fully developed. Students apply these concepts to the world around them and the use of technology.

1. Use the Periodic Table to explain and predict similarities in the chemical and physical properties of substances.

2. Apply the principle of the conservation of mass to chemical reactions.

3. Explain the properties and behavior of matter in terms of the arrangement and properties of its atoms.

4. Use kinetic molecular theory to explain rates of reactions and relationships among temperature.

5. Develop hypotheses and design experiments to explain variations in the acidity or alkalinity (pH) of water samples.

CONTENT STANDARD: Students examine the origin and evolution of the universe, the solar system and the earth's place and importance within the cosmic context.

Students develop a knowledge of the properties of the earth, sun and moon and their interaction. Students understand the impact of these bodies on changing seasons, the formation of tides, and life on earth. They also examine the scale and contents of the entire solar system, make comparisons among the planets, and learn about space exploration.

What a student should know and be able to do by the end of Grade 3:

Space science at this level should be observational and qualitative in nature. Students should, through short and long term observations, be able to describe what they see in the day and night sky. They observe, record and discuss size, shape, brightness, numbers of objects, and length of day and night and time between phases of the moon.

1. Observe, describe and explain patterns of daily, monthly, and seasonal changes in the physical world. (See also Earth Sciences).

2. Identify observable characteristics that enable classification of objects seen in the day and night sky.

3. Describe a timeline of key events in the exploration of space.

What a student should know and be able to do by the end of Grade 5:

Students begin to develop an inventory of the objects in the solar system. They explain why and how planets differ from stars in appearance and motion (e.g., Planets change their position against the pattern of stars that stay the same as they move across the sky).

1. Create models, drawings, or demonstrations to describe how the arrangement and movement of objects in the solar system explain daily, monthly, and seasonal changes.

2. Describe the shape and surface shading of the phases of the moon over a period of time.

3. Demonstrate a knowledge of the principles of rocket powered flight. (See also Physical Science: Energy).

4. Research and discuss the nature and conditions of outer space.

5. Design a experiment by which to determine the conditions which must be provided to support life in space. (See also Life Sciences).

What a student should know and be able to do by the end of Grade 8:

Students begin to learn the complexities of space through the use of technology and the construction of models based on observations and measurements. They are introduced to the notion of scale and distance measurement.

1. Use astronomical instruments to collect data to describe and record the relative positions and motion of the moon and sun over a few hours, days, and months.

2. Design and construct models which show the relative size and position of planetary objects in the solar system.

3. Relate a simple model of the solar system to day/night and year length, changes of day length, seasonal changes and changes in the inclination of the sun.

4. Investigate and compare the relative size, position, and motion of the moon, stars and planets.

What a student should know and be able to do by the end of Grade 11:

Students develop a mental model of the universe which reflects the known properties of space and its objects from an earthbound perspective including the scale and the age of the universe, the solar system and the earth. Students develop evidence to support the conclusion that such things as the universal law of gravitation and the nature of light are invariant for space-time. Further, the students explore various commercial ventures that are planned in space such as communication, pharmaceuticals and metallurgy.

1. Use models to explain how the Earth, Moon, Sun, and planets move relative to one another.

2. Use data on the solar system or other stars to speculate on the condition of other planets.

3. Relate current theories of the origin of the Earth and the universe to those of the past and of other cultures.

4. Relate the idea of gravitational force to the behavior of tides, the motion of planets, satellites and the possibilities and limitations of space travel.

5. Examine and provide examples of the astronomical influences on the Earth's climate.

6. Gather information and debate the benefits and problems of space exploration.

CONTENT STANDARD: Students acquire an understanding of the basic concepts of systems and their uses in explaining phenomena within the context of science and technology.

Students learn that a system is a bounded set of related parts or elements which function as a whole to serve a common purpose. Students investigate interrelationships between wholes and parts and observe patterns of change in both living (biological) and non-living (mechanical) systems. All systems can be described in terms of certain characteristics and are controlled by certain laws and principles.

Students demonstrate a basic understanding of natural systems by identifying the system, its purpose, subsystems, boundaries, hierarchies, energy flows (inputs, outputs), self-regulating mechanisms (feedback mechanisms), and the relationships of the parts. Students also identify technological systems, and man-made systems that have been designed to achieve a specific purpose. They demonstrate a basic understanding of technological systems by building and controlling simple systems and/or using computer-based simulations.

What a student should know and be able to do by the end of Grade 3:

Students work primarily with simple mechanical systems to develop the basic concepts of systems thinking. These concepts are then applied to simple studies of the natural world as a part of the study of Life Sciences.

1. Examine several simple systems (family, bicycle) and identify the parts of the system and their purposes.

2. Identify and describe common natural phenomena that can be considered to be a system.

3. Identify types of substances that enter (inputs) or leave (outputs) natural systems.

4. Assemble and operate a simple technological system (a mechanical toy, Lego or Erector set system), and identify the component subsystems.

What a student should know and be able to do by the end of Grade 5:

Students examine the basic properties of natural and technological systems, identifying inputs and outputs. Technological systems (structural, mechanical, electrical and fluid) are designed by humans to satisfy a need or want. Because human endeavor exists in the context of a larger environment, technological and natural systems interact and technological systems impact the natural world.

1. Disassemble a manufactured product and determine the types of subsystems found (structural, mechanical, electrical, control, etc.).

2. Select a technological system and develop an illustration that identifies the system's components; input and output, feedback mechanisms, energy flows, boundaries.

3. Construct a simple flow chart of a process within a system.

4. Identify desirable and undesirable outputs from technological systems and their impact on the natural world.

5. Investigate and construct a working model that demonstrates how mechanical systems control and transfer energy.

What a student should know and be able to do by the end of Grade 8:

Students deepen their technological knowledge and capability in the application of systems of technology. Through exploration and investigation, students begin to analyze, design, assemble, and troubleshoot systems. They begin to generalize about natural and technological systems.

1. Investigate and categorize the parts of several systems in relationship to the universal system components: input, process, output, feedback, resources.

2. Assemble, operate, and explain the operation of technological systems which produce outputs. Recommend ways to avoid undesirable outputs.

3. Use diagrams to show that output from one part of a natural or technological system can transfer as input to other parts of the system.

What a student should know and be able to do by the end of Grade 11:

Students gain additional knowledge and understanding about a variety of systems. They identify interactions among the elements of systems and gain experience with the feedback and control of systems.

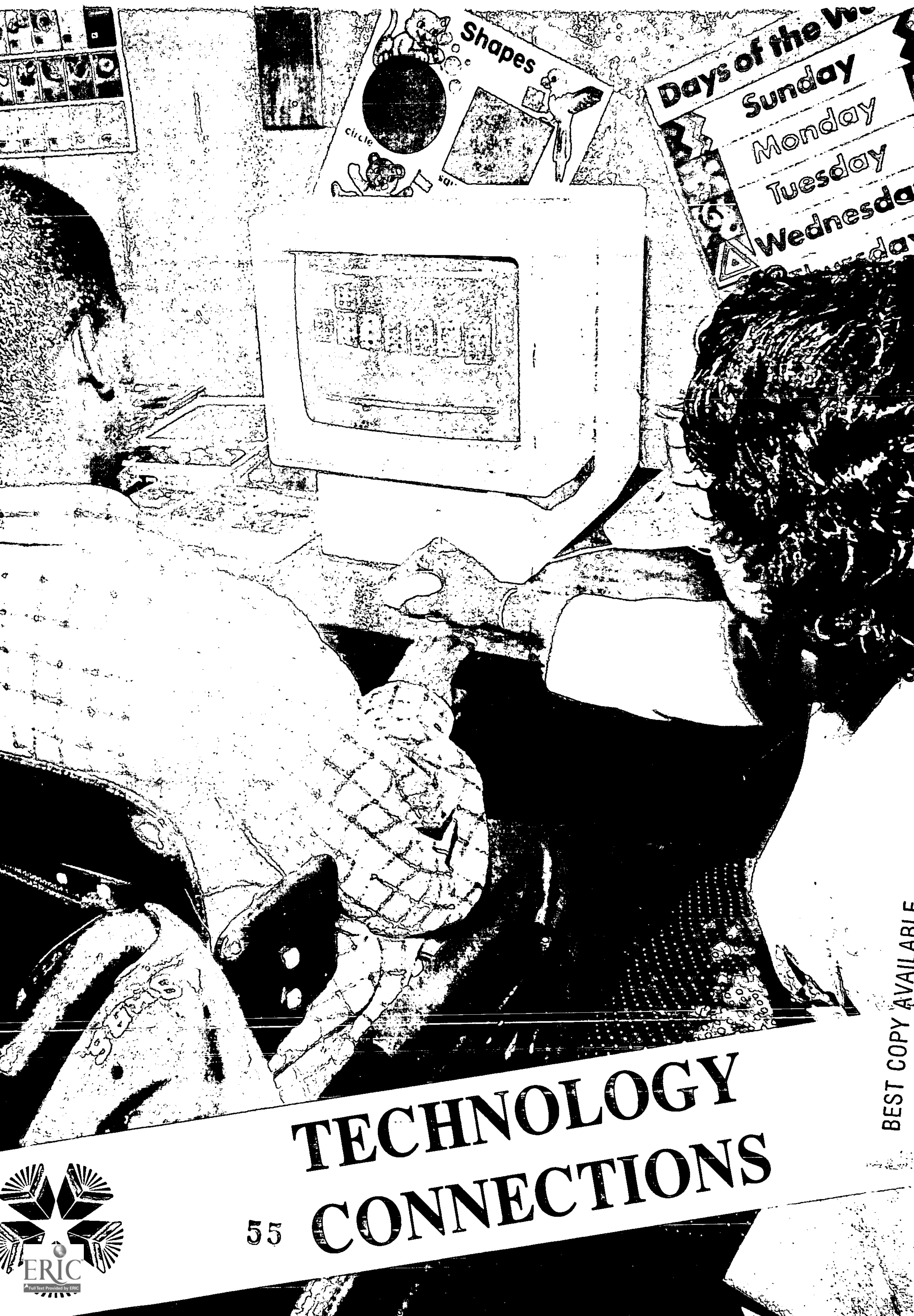
1. Explain and exemplify how modern technologies involve the interaction of numerous science-based technological systems.

2. Design and model a technological system that addresses a societal or environmental issue (waste disposal, water quality, mass transit).

3. Design, assemble, operate, and test a feedback control system to produce a product, energy, or information. Define its components, command and resource inputs, process, outputs, and the monitoring and control functions.

4. Investigate a complex physical or living system (e.g., photosynthesis in plants, chemical reaction, etc.), vary the input, monitor the effects upon the output, and summarize the relationships.

5. Apply systems thinking to propose solutions to unfamiliar, complex problems.



TECHNOLOGY CONNECTIONS

TECHNOLOGY CONNECTIONS: MATHEMATICS

The mathematics education community agrees that learning is enhanced by involving students in problem solving experiences and projects that have meaning. By addressing students' learning styles to improve retention, by working in groups that foster group decision making and interpersonal skills and by using technology, teachers can make learning exciting and engaging for all students.

In order for the District of Columbia Public Schools standards to be fully realized, technology in the daily school lives of students must become a reality. Technology needs to be incorporated into mathematics teaching and learning.

Content

- Content should emphasize real contexts and audiences other than the teacher, which call for the intelligent use of estimation, mental math, and number sense in which students can determine when technology is appropriate to perform calculations.
- Include service-learning projects and investigations that use technology to help students make connections among the different standards of mathematics and with other disciplines.
- Revise courses to include the use of calculators and other technology, and reduce emphasis on procedural and symbolic manipulation skills.
- Add topics that reflect an integrated approach to mathematics so that computers and calculators enable students to make connections between data analysis and algebra, and between algebra and geometry.
- Use calculators and computers to help students research, investigate, and develop conceptual understanding in order to build mathematical intuition.
- Add topics that are easier to teach using new technologies, and that will be needed to do mathematics in the twenty-first century.

PERFORMANCE-BASED LEARNING ACTIONS WHEEL

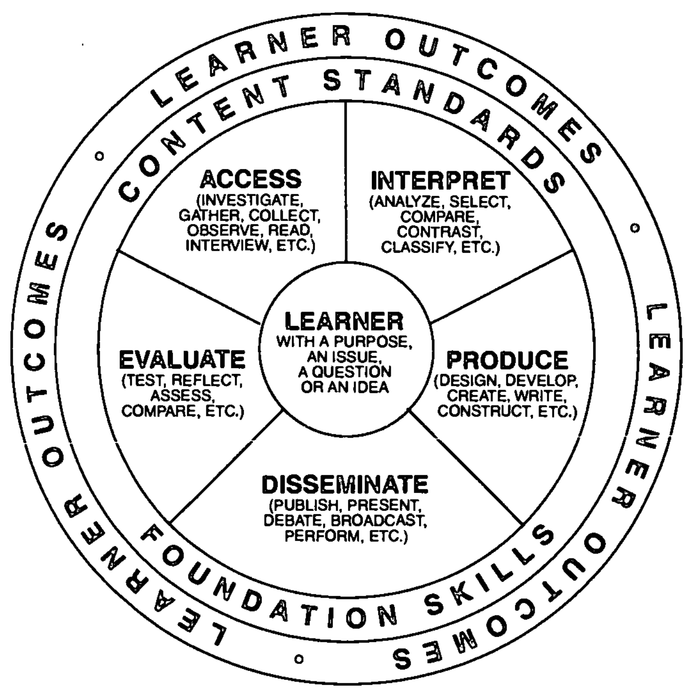


Figure 3

Instruction

- Move away from cumbersome rule based mathematics and rote drill and practice which establishes the teacher's role as information giver and answer confirmer.
- Use group exploration with calculators, databases, spreadsheets, and computer environments that revolve around open-ended problems or projects that have more than one solution.
- Employ multimedia technology to reach the diverse learning styles of students.
- Emphasize estimation and visualization using conjecture which can be confirmed through computer and calculator use.
- Diversify instruction by using technology to take advantage of whole class, small group, and one-on-one opportunities.

Assessment

- Avoid assessments that stress computation only and do not assess conceptual understanding.
- Increase the use of assessments that require calculator and computer, and encourage student investigations through the use of technology.
- Use assessments that reflect the changes made in content and instruction.
- Encourage students to make connections between language and mathematical representations by constructing answers to open ended or essay questions with the use of a word processor that imports graphs and charts.

A chart of recommended ways to integrate technology in teaching the content standards is presented on the next page.

Overview of K-12 Technology Integration
Mathematics

STANDARD	INTEGRATING TECHNOLOGY
Number Sense and Numeration Systems	Explore and calculate using calculators, computers, and other technology. Use technology to explore scientific notation, exponents, and order of operations. Use computers and graphing calculators to explore discrete mathematics topics.
Patterns, Relationships, and Functions	Explore patterns with calculators and computers. Verify function values and investigate using graphic utilities and numeric processing software. Use graphic utilities and numeric processing software to analyze the behavior of functions, sequences, and series.
Geometry and Spatial Sense	Explore geometric shapes and solve geometric problems using a variety of technology. Explore and create constructions using software. Draw geometric shapes using graphics software. Use geometric exploration software.
Measurement	Select and use appropriate tools. Investigate the effects of measurement changes using technology. Justify selection of measuring tools using precision. Use software for measurement to facilitate other learning.

Probability and Statistics	Use a variety of technology to analyze data and represent it graphically. Explore and produce graphic representations of data using calculators and computers. Calculate, analyze, and measure central tendency. Graph, plot, and draw lines of regression using software. Evaluate central tendency, dispersion, and relationships of data using calculators or software. Use computer networks to gather research data. Generate random data.
Algebraic Concepts and Operations	Explore variables using a variety of technologies. Use appropriate tools to show relationships between quantities. Verify the results of substituting variables. Create and explore models using graphing utilities and symbolic and numeric solvers. Recognize the capabilities and limitations of present technology. Analyze the behavior of functions using graphs.

TECHNOLOGY CONNECTIONS: SCIENCE

With the growing importance of technology to scientific research, teachers and students need to be able to access information, produce data in different formats, use software applications that simulate laboratory experiences and generally integrate new technologies into teaching and learning. The use of technology can make learning exciting and relevant and can help students meet their educational goals.

To help students achieve the DCPS learner outcomes and content standards, the use of technology must be integrated throughout the instructional program in science. The infusion of technology in the school lives of students will enable them to be better prepared and motivated for entering a highly technological work force.

Content

- Content should emphasize real life situations and require the intelligent use of technology to create models, make simulations, develop hypotheses, collect and investigate data, and draw conclusions.
- Include projects and investigations that use technology to help students better understand content, develop effective scientific thinking skills, and make applications of science content and concepts to their personal lives.
- Upgrade the use of classroom software to challenge students' thinking and avoid drill and practice usage.
- Design instructional units that use appropriate technology to achieve integrated approaches to teaching science.
- Include topics that allow students to use calculators and computers to collect, graph, and interactively view and analyze scientific data.
- Add technology enriched topics and experiences that cover the wide range of students' learning styles and abilities.
- Add experiences that connect academic work to the world of work.

PERFORMANCE-BASED LEARNING ACTIONS WHEEL

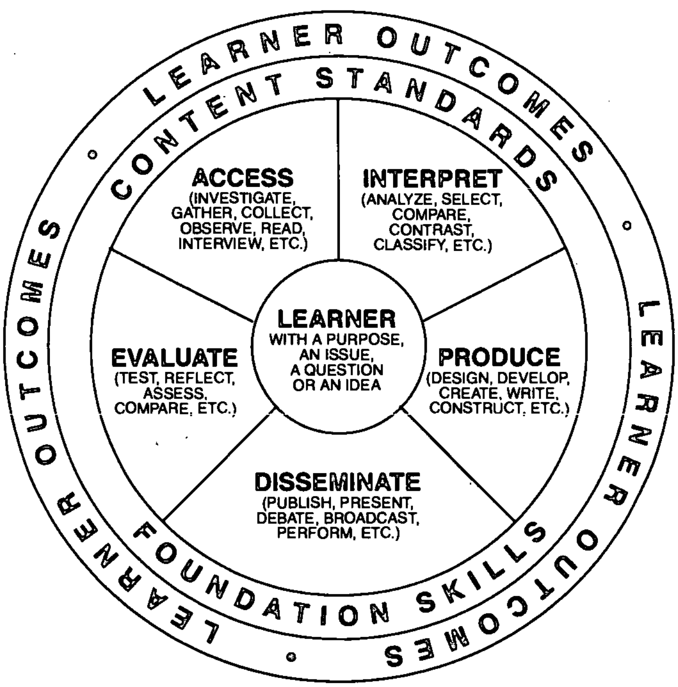


Figure 3

Instruction

- Move away from strict equation based science and "cookbook" laboratory experiences that establish the teacher's role as information giver and answer confirmer and move toward concept oriented instruction.

- Use group exploration with calculators, databases, spreadsheets, and computer environments that revolve around open-ended problems or projects that have more than one solution.

- Employ multimedia technology to reach the diverse learning styles and abilities of different students.

- Emphasize problem-solving and conceptual understandings which can be illustrated through computer and calculator use.

- Diversify instruction by using technology to take advantage of whole class, small group, and one-to-one opportunities.

Assessment

- Avoid assessments that stress rote memorization and do not stress conceptual understanding.

- Increase the use of assessments that require calculators and computer use.

- Use assessments that reflect the changes made in content and instruction.

- Encourage students to make connections between language, mathematical, and scientific representations by constructing answers to open ended or essay questions with the use of computer applications that import graphs and charts.

A chart of recommended ways to integrate technology in teaching content standards is presented on the next pages.

Overview of K-12 Technology Integration
Science

STANDARD	INTEGRATING TECHNOLOGY
Scientific Inquiry	◦ Use videos, computer software, and other technology to help students understand basic scientific concepts and increase interest in and knowledge of the natural world. ◦ Use the computer to formulate questions for scientific investigation. ◦ Use the computer to acquire, analyze and present information in meaningful ways. ◦ Use fax machines and the internet to receive and send scientific data.
Life Sciences	◦ Explore Distance Learning Programs to support classroom instruction or provide learning experiences or courses not available in the system such as the "Human Genome Project" or the "Private Universe" from Harvard University. ◦ Draw and examine specimens using graphics software. ◦ Dissect organisms, study and compare their anatomy using computer applications. ◦ Observe the division of cells, the birth of an organism, or other wonders of nature by using videos featuring special photography applications.
Earth Sciences	◦ Access remote-sensing images from orbiting satellites to obtain weather and environmental information. ◦ Experience the evolution of a hurricane or other severe storms on video.

	• Collaborate with local television station meteorologists to use broadcast weather maps in the classrooms. • Study land formations in print, or video or computer DC-ROMS.
Physical Sciences	• Use computer software to investigate and measure matter. • Plot experimental data by using computer graphing programs. • Establish databases containing information on topics such as "Chemicals and Their Properties" to sort, organize, compare, and search data. • Use spreadsheets to record and analyze physical data including averages, statistical distribution, or mathematical functions.
Space Sciences	• Visit space or a faraway place of interest on the planet through videotapes, instructional television, film, or slides. • Explore space on computer simulated space flight mission. • Study the planets and outer space with laser disc programs.
Systems	• Explore technological design and demonstrate how science often advances through the use and improvement of technology. • Use computer programs to design solutions to problems and understand the relationship between science and technology. • Investigate technology products and systems in the everyday world.

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CURRICULUM INTEGRATION

CURRICULUM INTEGRATION

Foundation Skills and Curriculum Integration

Foundation skills cross all subject areas.[1] They represent the building blocks for achieving the District's content standards and the learner outcomes. These skills are taught, practiced, and applied throughout the curriculum from kindergarten through twelfth grade. The four major categories follow.

I. **Communication** Communication is fundamental to all subject areas and to success outside school. Communication skills include reading, writing, listening, and speaking as well as non-verbal expression and the use of symbols, images, and sounds to express meaning. Opportunities to communicate help students construct knowledge, learn other ways to think about ideas, and clarify their own thinking.

II. **Reasoning and Problem Solving** Making sense of the world, being able to solve problems, and making decisions is essential to learning. Students need to learn how to analyze, hypothesize, synthesize, and generalize. Students who use skillful reasoning and problem solving processes increase their probability of success in the future by making good decisions about life.

III. **Personal Development and Social Responsibility** When learners take responsibility for their lives and actions, they develop essential work and learning habits. Students must learn to show respect for others and for their environment and to recognize that their actions affect the lives of others. Such skills are fundamental to the development of good citizenship and strong communities.

IV. **Making Connections** Students need to be able to make connections between one academic subject area and another and between what they learn in school and what is happening in the world outside school. These connections are often made clearer if teachers take a multi-disciplinary, interdisciplinary or integrated approach to teaching. The connection between education and life can also be made clearer to students if they apply what they learn in authentic situations or if their learning experiences are extended to settings outside the classroom, whether through internships and apprenticeships or through service learning.

PERFORMANCE-BASED LEARNING ACTIONS WHEEL

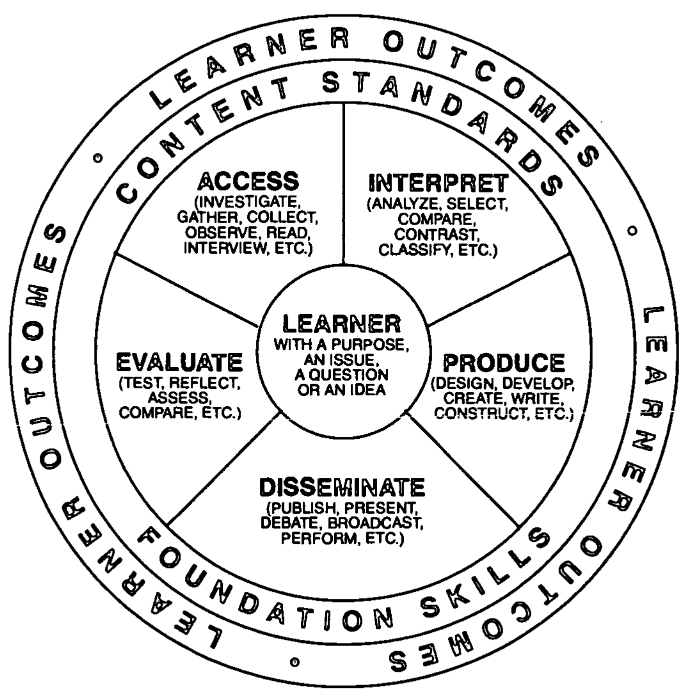

Figure 3

All teachers share responsibility for developing foundation skills in all students. In the *SCANS Report*, from the Secretary of Labor's Commission on Achieving Necessary Skills, a three part foundation is described for workplace competency:

- basic skills (reading, writing, listening, speaking);
- thinking skills (decision-making, problem solving, reasoning); and
- personal qualities (responsibility, sociability, self-management).

The District of Columbia Public Schools foundation skills mirror these workplace essentials.

On the Learning Actions Wheel, foundation skills frame the learning actions, along with the content standards that are specific to each discipline. The Learning Actions Wheel is illustrated in Figure 3.

To further define what students should be learning as part of their foundation skills, performance indicators for each skill are listed that describe what students should be able to do as they progress from kindergarten through twelfth grade.

I. Communication

1. Students read to understand and read to interpret a variety of materials by

a. Demonstrating understanding of increasingly complex text
b. Reading for a variety of purposes
c. Improving comprehension by using a variety of strategies
d. Reading sources that incorporate a variety of types of language: narrative, graphical, symbolic
e. Finding, interpreting, and synthesizing information from a variety of primary and secondary sources

2. Students write effectively for a variety of purposes by

a. Using the elements of effective writing: purpose, organization, details, voice, usage, and grammar
b. Developing thoughts, sharing information, influencing and persuading, creating, and entertaining
c. Evaluating both process and product with regard to appropriate conventions (spelling, usage and punctuation), forms of expression for different audiences (style and voice), process (drafting, revising and editing), and tools (technology and media)

3. Students listen actively for a variety of purposes by

a. Analyzing and clarifying information based upon what is heard
b. Responding to what is heard in a variety of ways —writing, interpreting, making connections, questioning, critiquing, and probing
c. Following directions

4. ***Students express themselves with power and purpose*** by

a. Demonstrating verbal and non-verbal communication skills by presenting works in public or by constructively asserting preferences, feelings, and needs
b. Speaking using appropriate conventions (usage and word choice), forms of expression (style and voice), and tools (technology and media)
c. Using a variety of models, media, and sources of information to create individual and collaborative works
d. Reviewing, editing, and adjusting products and performances to best match the audience and the purpose

5. ***Students use the tools of information technology to communicate*** by

a. Using computers, current systems of telecommunications, and other technological tools for a variety of purposes, especially communication and research
b. Using technologies to gather, store, manipulate, and present ideas and data in a variety of ways
c. Using libraries and other systems of information

II. Reasoning and Problem Solving

1. ***Students ask meaningful questions*** by

a. Generating a range of types of questions, from basic to complex, and identifying problems to be solved
b. Exploring questions about the major unifying themes across content areas and making interconnections between disciplines

2. ***Students choose and use effective means of solving problems*** by

a. Using methods of inquiry that include exploration, evaluation, and the scientific method
b. Finding meaning in patterns, connections, and applications
c. Using processes of research —planning, implementation, evaluation, modification, and reevaluation.
d. Using primary and secondary sources to gather information
Analyzing the validity and significance of sources and interpretations

3. ***Students approach problem solving with an open mind, healthy skepticism, and persistence*** by

a. Applying prior knowledge, abstract thinking, curiosity, imagination, and creativity.
b. Responding to new information by reflecting on experiences and considering sources of information
c. Demonstrating a willingness to try new methods and strategies in order to learn and persevere in the face of challenges and obstacles

4. ***Students think abstractly and creatively*** by

   a. Examining complex webs of causes and effects in relation to systems and events
   b. Using models to demonstrate ideas and connections
   c. Making aesthetic judgements based on explicit criteria
   d. Generalizing and visualizing new ideas

III. Personal Development and Social Responsibility

1. ***Students develop a unique sense of worth and personal competence*** by

   a. Assessing their own learning using criteria they have developed for themselves
   b. Demonstrating respect for themselves and for others
   c. Pursuing intellectual activities for personal enjoyment
   d. Setting priorities and accepting responsibilities for personal decisions and actions

2. ***Students develop productive and satisfying relationships with others*** by

   a. Performing effectively on teams
   b. Interacting respectfully with others, including those with whom they have differences
   c. Eschewing aggressive behavior

3. ***Students respect and value human diversity as part of a multicultural society and world*** by

   a. Expanding and enriching their understanding of world community through cross-cultural contacts
   b. Respecting diversity in social, artistic, and philosophical expressions
   c. Demonstrating an understanding of the concept of prejudice and its effect on people

4. ***Students act out of respect for all forms of life and take steps to protect and repair the environment*** by

   a. Taking an active, positive role in the community
   b. Working cooperatively with groups to set community goals and solve common problems
   c. Demonstrating an understanding of the value of the natural environment to human beings

IV. Making Connections

1. ***Students complete projects, papers, performances or exhibits that are multi-disciplinary*** by

   a. Choosing topics of interest to research and study that cross disciplines
   b. Analyzing how different disciplines approach the same subject or object of study from different perspectives
   c. Using multiple intelligences to acquire and present information
   d. Demonstrating understanding of connections to a common theme within and among disciplines

2. ***Students apply what is learned to authentic situations*** by

   a. Identifying new situations in which to apply new learning
   b. Drawing real world examples from classroom learning
   c. Explaining how to use classroom learning in everyday situations

3. ***Students participate in community, workplace, and other external learning environments*** by

   a. Exploring career options in several disciplines
   b. Shadowing or interning at a workplace site
   c. Interviewing workers and professionals about connections between what they learned in school and what they do in their jobs
   d. Engaging in service learning

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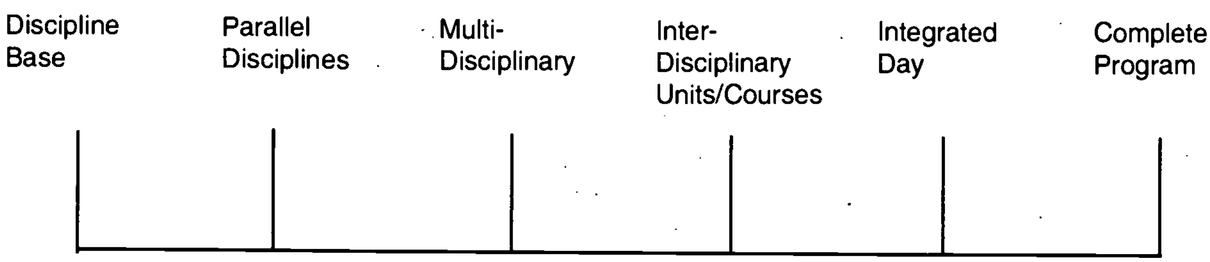
1 Adapted from the *Content Standards for Vermont's Common Core Framework for Curriculum and Assessment*,

Curriculum Integration

While the DCPS curriculum framework documents are organized by disciplines, teachers are encouraged to consider possibilities for integrating instruction. That is not to say that all curriculum should be integrated, or that no lessons should be discipline-specific. But instead, all students should experience a range of content design from the discipline-specific to the fully integrated. Heidi Hayes Jacobs presents that range of designs as a continuum of options for teachers. (See Figure 4).

Figure 4

Continuum of Options for Content Design*



*Heidi Hayes Jacobs, *Interdisciplinary Curriculum: Design and Implementation*, ASCD, 1989.

The choices teachers make along the continuum depend to a great extent on their school environment and organization, their willingness to work with other teachers and to experiment, and their knowledge of interdisciplinary teaching. According to Heidi Hayes Jacobs, the options are defined as follows: [2]

***Discipline-Based Content Design**:* The discipline-based content design option focuses on a strict interpretation of the disciplines with separate subjects in separate time blocks during the school day.

Parallel Disciplines Design: When the curriculum is designed in a parallel fashion, teachers sequence their lessons to correspond to lessons in the same area in other disciplines. For example, if the social studies teacher teaches a unit on the Civil War in the spring semester, the English teacher will reschedule her autumn book, *The Red Badge of Courage*, to coincide with the social studies unit.

Complementary Disciplines, Units or Courses: The complementary option suggests that certain related disciplines be brought together in a formal unit or course to investigate a theme or issue. Complementary disciplines might be English, history, art and music that together make up a humanities course.

***Interdisciplinary Units/Courses**:* In this design, periodic units or courses of study deliberately bring together the full range of disciplines in the school's curriculum. Usually teachers plan their interdisciplinary units around themes and issues that emerge from their ongoing curriculum.

Integrated-Day Model: This model is a full day program based primarily on themes and problems emerging from the student's world. The emphasis is on an organic approach to classroom life that focuses the curriculum on the student's questions and interests rather than on content determined by a school or district syllabus.

Complete Program: This approach is the most extreme form of interdisciplinary work. Students live in the school environment and create the curriculum out of their day-to-day lives.

Teachers are encouraged to combine design options in the delivery of instruction. In order to accomplish interdisciplinary and integrated curriculum and instruction, time must be set aside for planning, research, communication, and coordination with colleagues. Another important practical consideration in implementing interdisciplinary instruction is scheduling. Students and teachers must be scheduled so they are available for each other as required by the design of the unit or course. There should be common planning time for the teachers as well.

Students should have a range of curriculum experiences that reflects both specific disciplines and an interdisciplinary orientation. Research has shown that students cannot fully benefit from interdisciplinary studies until they acquire a solid grounding in the various disciplines. Interdisciplinary curriculum experiences, however, provide an opportunity for a more relevant, less fragmented, and stimulating experience for students.

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2 Heidi Hayes Jacobs, *Interdisciplinary Curriculum: Design and Implementation*, Association for Supervision and Curriculum Development, 1989.

USING THE FRAMEWORK

Using the Curriculum Framework

For students to be successful, instructional programs must have clarity of focus, high expectations and expanded opportunities for students to learn. Performance-Based Education creates a systemwide focus for instruction and sets high expectations for student performance. The instructional focus is defined by the District of Columbia Public Schools learner outcomes, the content standards, and the foundation skills.

High expectations for all students are benchmarked at grades 3, 5, 8 and 11. At these gates, quality performances must be demonstrated before a student may move to a higher level. In order for every student to meet the standards, they must be actively and deeply engaged in experiences that will develop their knowledge of content, their skills, and their attitudes toward learning.

The starting point for the creation of engaging instructional units are the DCPS learner outcomes and content standards. All teaching and learning activities must be grounded in these, which are informed by existing and emerging national standards. Teachers must also help each student develop the foundation skills for excellent work in the content areas.

The curriculum framework is a reference document for teachers to use to identify the appropriate outcomes, standards and foundation skills for a unit of study. Since performance-based education is a teaching, learning and assessment system that focuses on actual student demonstrations of learning, teachers must determine at the outset how learning from the unit will be demonstrated and evaluated. Once a performance task and evaluation criteria are agreed upon, learning events can be created which will help students perform the task. These learning events must incorporate all of the learning actions on the performance-based learning actions wheel:

- accessing information,
- interpreting information,
- producing something new,
- disseminating learning to an audience, and
- evaluating the learning performance.

(See next page for a more detailed description of the student learning actions).

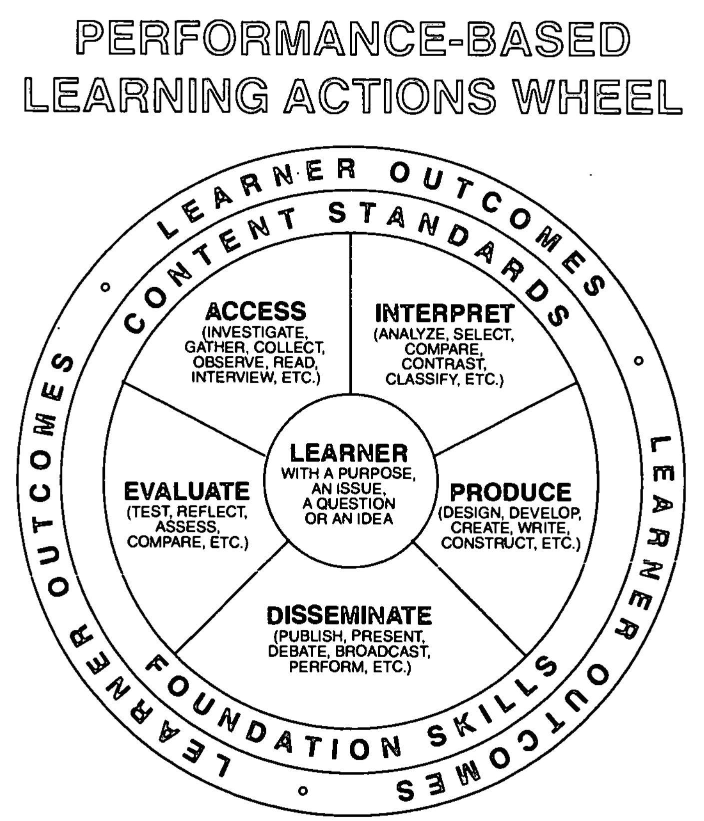

Figure 3

PERFORMANCE BASED LEARNING ACTIONS WHEEL
The Learning Actions

ACCESSING
Students need to learn how to find information. In this information age, with its dramatically expanding knowledge base, learning this skill means using computers in addition to traditional methods. Accessing involves a variety of processes that are key to achieving virtually all of the District's learner outcomes. It involves investigating, gathering, collecting, observing, reading and interviewing, to name a few. Each of these processes helps students obtain the information needed to carry out a successful learning demonstration.

INTERPRETING
Students determine how to make sense of the information, decide what it means, and how it compares with other information and ideas. It includes analyzing, selecting, comparing, contrasting and classifying, in addition to describing, explaining, and justifying the results of their interpretations.

PRODUCING
Students translate the results of their resarch and interpretation into tangible form. They may design, develop, create, build, construct, or organize a product or performance. This translation and creation action clearly relates directly to all six learner outcomes. This is really what it means to *apply* or *make use of* learning. Producing something tangible as a result of the learning effort is a powerful motivator for students, especially when there are real audiences and purposes for their efforts.

DISSEMINATING
Students relate to an audience or consumer by disseminating what they have learned. This connects school learning to the reality of other settings. At the heart of this action is communicating—publishing, presenting, debating, broadcasting, performing, or even marketing or selling.

EVALUATING
Students think about what has occurred while engaged in a learning unit; they review, revisit, reflect, assess, compare, and plan what needs to be done to make their learning more effective the next time. Learning is a continuous process, so evaluation represents both the end of one learning cycle and the beginning of another. The evaluation is viewed in the light of the performance criteria against which student work is evaluated. This strengthens students' ability to assess and direct their learning on a continuous basis.

Steps for Designing a Performance-Based Unit

How a teacher delivers instruction, the particular thematic focus chosen, and the kinds of learning events that occur will vary from teacher to teacher, for there are many roads to the same destination. However, in Performance-Based Education there is also a common set of elements that must be addressed in planning for instruction:

- the learner outcomes,
- the content standards,
- the foundation skills,
- performance tasks with articulated criteria, and learning events.

The flowchart below describes the steps for planning a performance-based unit. Each of those steps is described in more detail on the next pages. The process is ongoing and recursive, with teachers continually evaluating the effectiveness of the lessons, the performance tasks and criteria for moving students toward achievement of the Learner Outcomes.

DCPS Performance-Based Education
Unit Planning Flow Chart

Identify the Learner Outcomes, content standard(s) and foundation skills targeted in the unit.

↓

Develop the unit's essential question, problem or issue

↓

Design the performance task.

- How will students demonstrate their understanding of the essential question?
- What criteria will be used to measure student success?

↓

Specify the essential concepts, information and skills to be learned

↓

Create learning events that teach the key concepts and skills, using the learning action steps.

↓

Stage the performance task to answer the essential question and involve students in the assessment.*

*Refine the performance assessment and learning events before recycling the unit

1. Identify LEARNER OUTCOMES, CONTENT STANDARD(S) and FOUNDATION SKILLS to be addressed by the unit.

Teachers use the curriculum framework documents to identify the learner outcomes, content standards, and foundation skills on which the unit will focus.

2. Develop the ESSENTIAL ISSUE or ask an ESSENTIAL QUESTION.

Teachers, often in cooperation with students, raise an essential question or issue related to the content to be learned. The essential question or issue needs to help students make connections between what they are learning and the real world. The performance task is the means through which students exhibit integration and application of the content and skills they are learning as they respond to the essential question or issue.

3. Design the PERFORMANCE TASK.

Teachers, often in cooperation with students, design or adapt a performance task that will allow students to demonstrate acquisition, interpretation, and application of the most important material to be learned in the unit. The culminating performance task could be in the form of an essay, a project, an experiment, a portfolio, a recital, a video, or other possibilities. Whatever its form, the performance task should be authentic, that is, it must engage the students in intellectual work that simulates a task they might perform for a real audience and purpose. It also means that the performance task must have a set of clearly stated criteria for measuring the degree to which students have achieved the intended results.

4. Specify the INFORMATION and CONCEPTS to be learned.

Teachers identify the content information and key concepts that students need to know in order to perform the task. They must determine how students will learn the concepts and use them to produce what is required in the performance task.

5. Create LEARNING EVENTS.

Teachers create learning events and design lessons which engage students in accessing the key concepts and information, interpreting the content, producing something new with the information, disseminating it to an audience, and then evaluating their work. These events must be designed to appeal to the variety of ways students learn, recognizing students' multiple intelligences, languages, and cultures. Teaching strategies should include cooperative learning, inquiry based learning, problem or project based learning, demonstrations, simulations, and other opportunities for participation.

6. Stage the PERFORMANCE TASK through which students answer the ESSENTIAL QUESTION.

Teachers, in staging the task, provide adequate time and resources for the students to plan, practice, construct or write, share, revise, and polish their performance. They help students identify appropriate audiences for the performance.

7. Evaluate the PERFORMANCE TASK with students

Teachers consider ways to use criteria to involve the students in self-assessment throughout learning events, guided mini tasks, and the culminating task, so that students learn to critique and improve their own work and the work of others. This is particularly important for preparing students to become self-directed learners.

The PBE unit planning guide on the next page raises questions for teachers to consider as they plan a PBE unit. The PBE unit is designed to assist teachers in developing units that set high expectations for students, engage them in active learning, and establish clear criteria for measuring student performance

PERFORMANCE-BASED EDUCATION
UNIT PLANNING GUIDE

(1) DETERMINE STUDENT OUTCOMES, USING CURRICULUM FRAMEWORK DOCUMENTS.

- What do you want the students to know and be able to do at the end of this unit?
- Which Learner Outcome, content standards, and foundation skills will you target?

(2) DEFINE ESSENTIAL QUESTION, ISSUE or PROBLEM.

- What theme or topic are you studying?
- Why is this interesting to your students?
- What question or problem will engage them?

(3) DESIGN FINAL ASSESSMENT TASK.

- How will your students demonstrate their understanding of the essential question and their response to it?
- What vehicle will they use to present what they have learned? (e.g. writing, exhibition, performance, etc.)
- What criteria will you use to evaluate the final performance task?

(4) IDENTIFY ESSENTIAL INFORMATION, CONCEPTS AND SKILLS.

- What information, concepts and skills will students need to master in order to respond to the essential question and complete the final performance task?
- What is the most important information students should learn from this unit?

(5) CREATE LEARNING EVENTS.

- What assignments, lessons and activities will help your students meet the outcomes and respond to the essential question, issue or problem?
- What resources will you need?
- How will you develop your students' multiple intelligences and address different learning styles?
- Will you be able to integrate your instruction with another discipline?

(6) STAGE THE FINAL ASSESSMENT TASK.

- How much time will the final assessment take?
- Will students be engaged in the evaluation?
- Does the unit need to be refined?

Glossary

Assessment = Observation and/or measurement of what students know and can do.

Authentic Assessment = Assessment that is similar to something that a student might have to do in the world outside school.

Benchmark = Statement of skills and content that students must demonstrate at a specific point to show the progress they are making in learning.

Content Standard = Broad descriptions of the knowledge and skills that schools should teach and students should acquire in a particular subject area.

Criteria = Characteristics that clearly define and describe how a student's proficiency in a specific skill and/or content area will be measured.

Foundation Skills = Basic skills that cross all subject areas that schools should teach and students should acquire.

Gates = Specific grade levels by which students must demonstrate required content and skills before moving on to the next level. In DCPS, these are at grades 3, 5, 8 and 11 and at graduation.

Learner Outcomes = Goals which all students are expected to achieve by the time they graduate from the District of Columbia Public Schools.

Multiple Validations = The use of more than one type of assessment to verify that students have learned required skills and content.

Performance–Based Education = A system of teaching, learning, and assessing that requires student demonstrations of learning.

Performance Indicators = Expectations of what students should know and be able to do at a particular grade level to meet a content standard.

Performance Task = An activity or series of activities through which students demonstrate their acquisition of content and skills.

Portfolio = A systematic and purposeful collection of student work that reflects growth over time.

Rubric = A scoring scale use to measure the level of success on a performance task. It may be used for assessment purpose or for coaching students to higher level of performance.

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